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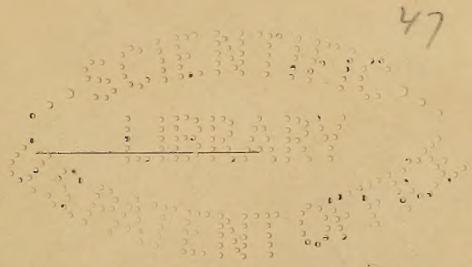

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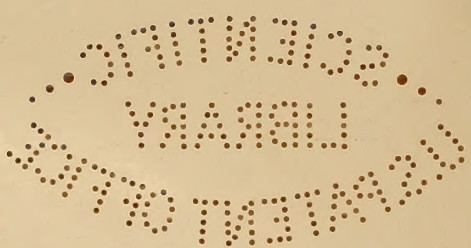

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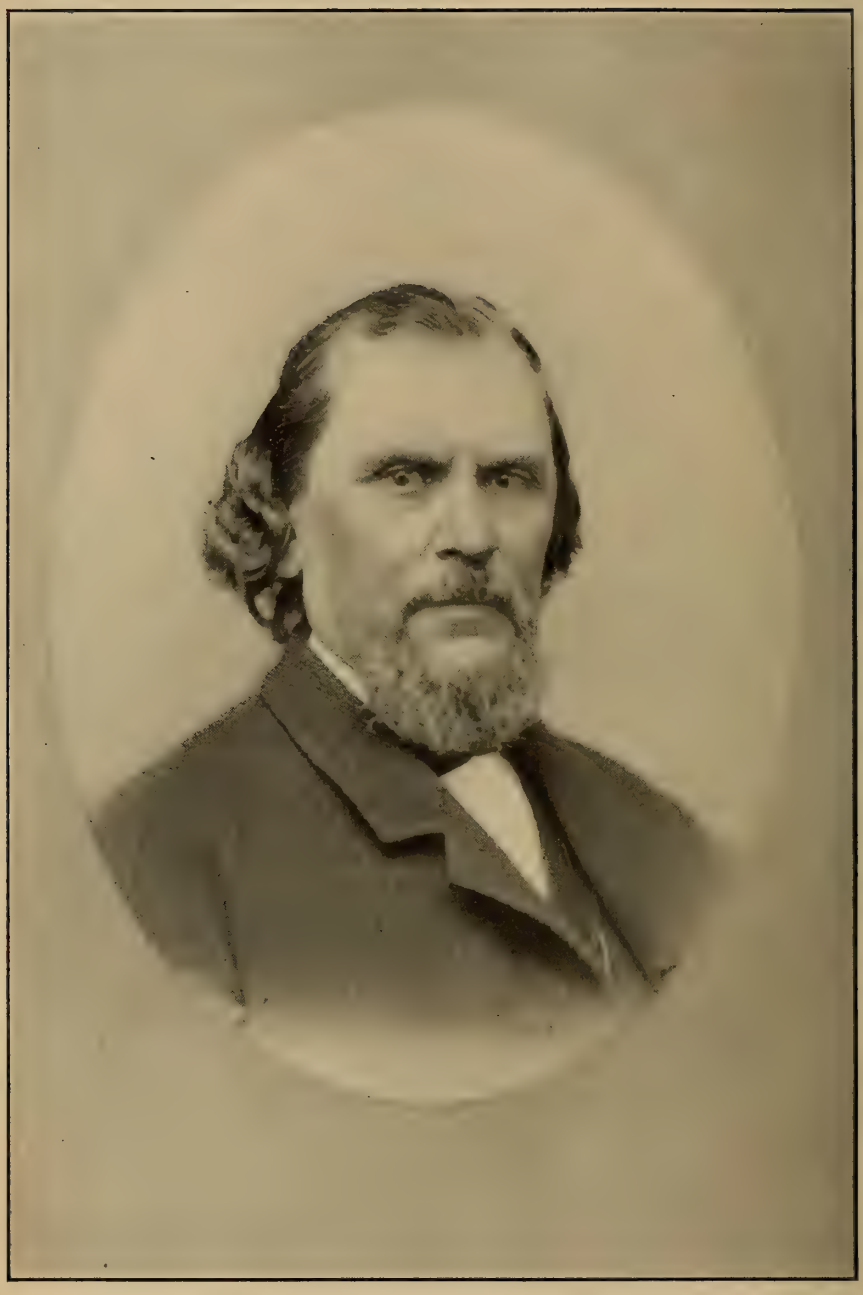

JOSEPH HARRISON, JR.

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CASSIER'S MAGAZINE

AN ENGINEERING MONTHLY

VOL. XXXVII NOVEMBER, 1909 No. 1

JAPAN

ITS IRON, STEEL AND SHIPBUILDING INDUSTRIES

By T. Good

WITH ample supplies of coal, iron, copper and tin, an advantageous geographical position, magnificent harbours, a favourable climate, an intelligent and energetic population, and an exceptionally business-like government, it is more than probable that Japan will soon become one of the world's greatest industrial countries. Indeed, the Britain of the East is already making almost giant strides toward a foremost position in the international commercial race, just as she rapidly and unexpectedly attained a high status as a fighting nation; therefore, a brief account of her industrial progress and resources may not prove uninteresting.

To begin with, there are not less than 1,200,000,000 tons of coal deposited in Japan. This coal is now being mined at the rate of 14,000,000 tons a year, the increasing rate of output being indicated by these figures:

OUTPUT OF THE COAL MINES OF JAPAN	Tons.
1891-5	3,742,000
1896-1900	6,613,000
1901-5	10,194,000
1906	12,974,000
1907	13,716,000
1908	14,468,000

The price of Japanese coal at the pit mouth in the three years 1906-7-8 averaged 9*s.* 2*d.* per ton. Most of the coal is of a bituminous quality, and makes very good coke. In 1907 Japan exported 2,922,000 tons of coal, the average price, f. o. b., being about 11*s.* per ton. The commercial value of the coal may be judged by the fact that 141,000 tons were exported to the United States! Bunkers accounted for no less than 1,197,000 tons in 1907. The coal seams usually vary from 3 to 8 feet thick, and are mostly so conveniently situated that they can be worked by incline, there being very few shafts in operation yet. Some shafts are, however, being sunk to a depth of 1,000 feet, and two 900-foot shafts have just recently started working. In the north, in the island of Hokkaido, a coal field containing thirteen seams, of which the thinnest is 3 feet thick, has been discovered; in another part of the same island twenty seams have been found, five at least being workable; while in still another district there are three excellent seams, of which one is 25 feet thick and of great extent. In the south, in the Island of Kyushin, the coal measures are at least 30 miles long by from 8 to 16 miles wide, and are estimated to contain 600,000,000 tons, or about half the entire quantity in sight in Japan. The Japanese coal mines now employ nearly 60,000 hands, the annual per capita output being about 240 tons. The largest

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GOVERNMENT BUILDING, TOKYO

mine in Japan—the Manda—has a shaft 41 feet by 12 feet, 896 feet deep, and a daily output of 1,100 tons. Nearly all the cutting in Japanese mines is done by hand; but machinery is being introduced, and it is hoped that cost of production will be reduced. So far as coal is concerned, the industrial future of Japan seems well assured.

We have no authoritative estimate of the quantity of iron ore available; but some very rich and extensive deposits have ben found in the southwest, near the port of Sakai, about 100 miles from Osaka, and a similar distance from the coalfields of Kyushio. Considerable deposits are also known to exist near the ports of Miyako and Minato, in the northeast, as well as in central districts near the gold fields which lie between Tokio and the west coast. In 1907 over 5,500 tons of chromic iron and 10,000 tons of manganese were raised in Japan.

At present Japan depends almost entirely upon ore imported from China for the 40,000-odd tons of pig-iron she makes annually. The ore is brought from the Pinghsiang mines, about 200 miles up the river Tayeh, down to Hankow in steel lighters, and then shipped in larger vessels to Japan via the Yang-tse-Kiang and Yellow Sea. As this Chinese ore yields a remarkably high percentage of iron—sometimes running up to 65 per cent.—and the supply is practically inexhaustible, our budding rivals are in no danger of running short of raw materials, although their price is somewhat high yet. Incidentally, it may be mentioned that Chinese basic pig-iron, produced at the Hanyang Iron & Steel Works, near Hankow, 600 miles up the river, has been delivered in the United States—at New York, in fact, 14,000 miles distant—at 70*s.* per ton, cost and freightage.

The quantities and values of minerals and metals produced in Japan in 1906 and 1907 in English weights and coinage, according to the reports of the Department of Agri-

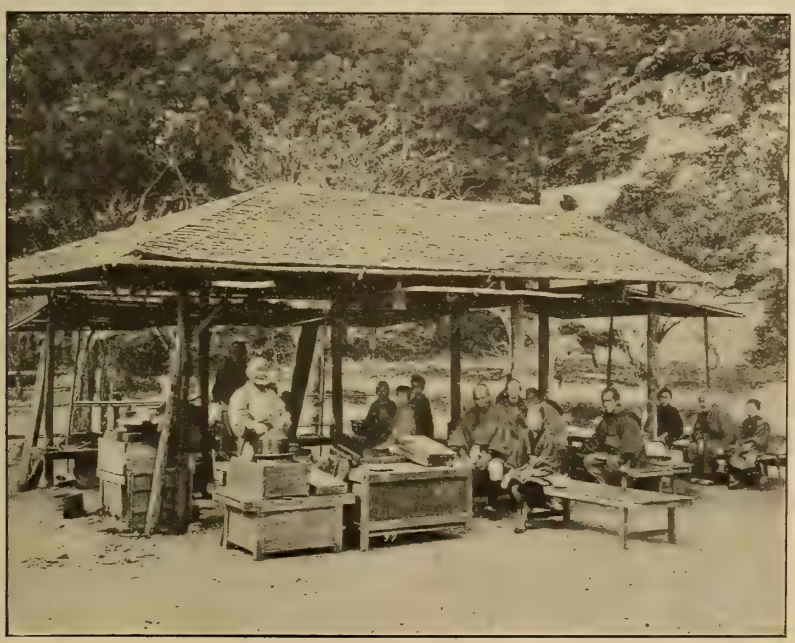
culture and Commerce, were as follows:

	1906 Quantity, Tons	Value, £
Coal	12,970,274	6,336,412
Pig-iron	38,945	193,968
Steel	3,162	25,407
Manganese	7,064	6,947
Copper	34,691	2,630,220
	1907	
	Quantity, Tons	Value, £
Coal	13,716,488	5,929,637
Pig-iron	42,919	213,758
Steel	4,520	36,323
Manganese	10,177	10,128
Copper	37,161	*2,700,000

* Estimated.

It will be seen that the price of Japanese pig-iron is very nearly £5 per ton, with steel at a correspondingly high figure—about £8 per ton. Naturally, this high cost of production is a serious matter; but efforts are being made to economise. In 1907 Japan imported more than £4,000,000 worth of iron and steel. On this point it is interesting to quote from a document issued recently by the government: "As regards the home supply of shipbuilding materials, great hopes are entertained that our shipbuilders will before long have ample supply of the necessary materials from the government steel foundry at Wakamatsu, and thus be freed from the disadvantages they have been laboring under through the importation of such materials from foreign countries."

The initial outlay on the Imperial Steel Works at Wakamatsu was unnecessarily heavy, and this has handicapped the enterprise somewhat; but the government seem determined to persevere, and, no doubt, they will meet with success, financially, before long, as they have already attained success mechanically. This plant is now in full operation, and employs over 7,000 men. The works comprise three blast furnaces, with a combined daily capacity of 450 tons of pig-iron; a 160-ton mixer and three cupolas; three Bessemer converters, each of 10 tons capacity; cogging, rail, bar, rod, and plate and sheet mills; crucible steel plant; wire-drawing plant; galvanizing and corrugating plant; boiler, engine and bridge shops; a railway 45 miles long, with 51 locomotives and 650



A JAPANESE WAYSIDE RESTING PLACE

ON THE BANKS OF THE SUMIDA RIVER, TOKYO

trucks, and loading and unloading arrangements. Rifles, heavy artillery, big guns for battleships, etc., are now being made in these works, and it is intended to so extend and develop the concern as to render the Japanese Admiralty practically independent of foreign steel and armament makers. New works are also to be erected at Mororau, near Yezo.

Besides the Imperial enterprise, a private firm has a steel foundry at Hiogo, and an Anglo-Japanese company has been formed, with a capital of £1,000,000, to undertake the manufacture of steel. Works are to be erected in the north, on the Island of Hokkaido, where there is plenty of coal. It has not yet been decided what ore will be used; but experiments are being made with local material, which is abundant, and if this proves satisfactory it will be much cheaper than fetching ore from the centre of China, as is done to feed the Wakamatsu furnaces. In short, industrial Japan, after having a very late start in the race, is now forging ahead very rapidly in most branches of manufacture and commerce. As evidence of the progress effected, it may be mentioned that the paid-up capital of Japanese industrial companies increased from £9,000,000 in 1896 to £25,000,000 in 1906. Next to textile undertakings, the metal and engineering branch of industries is absorbing the most capital.

Since 1896 the shipbuilding trade has made considerable headway, and promises to become a first-rank industry. The first shipyard in Japan worth mention was established by the government at Nagasaki Harbour in 1857, and two or three other yards and engine works were started by private capitalists shortly afterwards. In 1868 the Imperial yard was placed under the management of the special Industrial Department inaugurated by the present Emperor in the first year of his reign, and the construction of merchant vessels was undertaken. A few years later another Imperial yard was established at Kobe, and the best of the private works were nationalized, while several of the private builders of native boats extended their yards to accommodate something approaching the Western type of ship. But the progress was very slow, and as late as 1894 out of

THE RIVER FRONT AT TOKYO

eighty-four steamers of more than 1,000 tons owned in Japan only one had been built at home. In 1896, however, the industry received its first real impetus by the enactment of the Shipping and Shipbuilding Subsidies law, which granted bounties to all vessels of over 1,000 tons built and owned in Japan. Since then the following merchant tonnage has been built at home and added to the register:

	Tons		
	Steam	Sail	Total
1896	5,860	1,061	5,921
1897	10,693	2,472	13,165
1898	13,929	20,836	34,765
1899	18,157	20,342	38,499
1900	15,380	17,873	32,353
1901	31,829	20,255	52,084
1902	16,328	13,035	29,363
1903	33,612	9,925	43,537
1904	23,264	11,633	34,897
1905	33,039	16,457	49,496
1906	32,300	25,633	58,933
1907	70,870	3,782	74,652
1908	73,267	5,231	78,498

Besides these ships of commerce and a few built for other countries, there were launched from Japanese yards in the three years 1906-7-8 warships aggregating 103,140 tons and 193,500 I. H. P. Not only is Japan now constructing practically the whole of her own ships, both naval and mercantile, but is building some vessels on foreign account. Another ship subsidy bill is on the point of passing into law, works are being extended, vigorous efforts are being made to further cheaper cost of materials and construction, and it is more than probable that the British shipbuilder will soon have another formidable competitor.

BRIDGE AT TOKAIDO, JAPAN

The largest shipbuilding establishment in Japan is the one at Nagasaki, founded, as already mentioned, by the government in 1857. In 1884, however, this yard was sold to Baron Iwasaki, its present principal owner, and is now known as the Mitsu Bishi Works. This concern now consists of engine shops at Akunoura and a patent slip at Kosuge, besides the original and now famous yard at Tategami, Nagasaki. When the undertaking was sold by the Imperial authorities 800 men were employed. To-day 8,500 are employed. It was not until 1898 that the first 6,000-ton steamer was launched—the *Hitachi Maru*, for the Nippon Yusen Kaisha. The construction of this vessel, coupled with the ship subsidy law, of

ISHIBE—A JAPANESE TOWN IN THE INTERIOR

which she was really a product, marked the beginning of a new era in Japanese shipbuilding. Improvements and extensions followed rapidly, and the Mitsu Bishi is now one of the best-equipped establishments in the world. The building yard, which covers 115 acres, has nearly a mile and a half of water frontage and three dry docks of 350, 510 and 714 feet in length; a patent slip 750 feet long, and seven building berths, ranging from 185 to 700 feet long. Nearly all the machine tools, etc., are driven by electricity; there are shop, yard and wharf cranes of the latest pattern; electric hammers up to 150 tons striking force, and other up-to-date appliances, besides an excellent technical school on the works. Among the vessels built and fitted out at these works during the last two years, 1907-8, may be mentioned the following:

	Tons	I. H. P.
Mogami, turbine s.s.	1,350	8,000
Sakura Maru, turbine s.s.	3,204	9,148
Kamo Maru, turbine s.s.	8,700	7,000
Hirano Maru, turbine s.s.	8,523	7,600
Astuta Maru, turbine s.s.	8,523	7,600
Tenyo Maru, turbine s.s.	13,500	16,850
Chiyo Maru, turbine s.s.	13,500	16,850

This firm also built a floating dock of 12,000 tons lifting capacity last year at a new yard which they have opened at Kobe. This dock is made entirely of home-made steel. The two large turbine steamers named merit special praise. They attained over 20 knots on trial, and are fitted and furnished in the most lavish and luxurious style known to Japanese art. Rich silk hangings and embroidery are to be found all over the passenger quarters. On each vessel there are four suites of family rooms and 81 staterooms for 260 first-class passengers, and well-appointed quarters of 47 intermediate and 1,000 steerage passengers. There is ample bed, bath and lavatory accommodation, and the libraries, music, smoke and dining-rooms are gorgeously decorated. These vessels, which are on the trans-Pacific service of the Toyo Kisen Kaisha, are, in design and equipment, equal to anything on the Atlantic.

The new yard at Kobe, just mentioned, was commenced by the Mitsu Bishi about three years ago. Kobe is some 300 miles from Nagasaki. At this new establishment there are two floating docks, and besides doing repair work—the place is near Osaka, one of the chief ports and the sec-

ond largest town in Japan (population 995,000)—yachts and other small craft are being built. All the Mitsu Bishi works, it may be added, are now managed by Japanese engineers, only three English engineers of subordinate rank and a driver being employed by the firm.

The second largest shipyard in Japan is at Kobe, and owned by the Kawasaki Dockyard Company, who, in addition to this yard and the adjoining engine works, have a steel foundry at Hiogo. Like the Nagasaki yard, this one at Kobe was founded by the government, and then sold into private hands in 1886, passing into the ownership of the present company in 1896. This yard is now four times as large as it was when the State parted with it. Until quite recently only torpedo craft and small gunboats for the Japanese and Chinese Governments and medium-sized merchant vessels were built here; but last year two ships of 8,600 tons each, and another of 6,000 tons, were launched, while accommodation is being provided for boats up to 10,000 tons at least. There are now four building berths of from 400 to 600 feet in length, besides several others for small craft, the water frontage extending to nearly a mile. At this yard is a dry dock 377 feet long. The company's steel foundry, opened two years ago, can turn out first-class castings. Patent rights have been secured for the American Curtis steam turbine, while this firm's big rival at Nagasaki has rights for the British Parsons turbine. The Nagasaki company has already supplied a 9,000-I. H. P. set of Parsons to the government, and is now engaged on two sets of 9,000 and 17,000 I. H. P.

Third in importance among private shipbuilding establishments in Japan is the Osaka Ironworks, founded by an Englishman, Mr. T. H. Hunter, in 1880, and still owned by that gentleman. This concern comprises a building yard covering 16 acres at Sakurajima, engine shops at Ajikawa Guchi, and repairing works at Temposan. The Sakurajima yard has a water frontage of 1,000 feet and three dry docks; but no very large vessels are built here, as there is not more than a depth of about 14 feet in the river at this spot at low water. In the last two years, however, no fewer than twenty-nine ves-

A VIEW OVER THE TOWN OF MITSUKE

PARK AND OLD CHERRY TREE, KYOTO

sels have been launched, most of them being steam trawlers, whalers, dredgers, tugs, and a few vessels up to 1,800 tons.

Altogether, there are 216 private shipyards, with 72 dry docks, in Japan; but, as yet, only five of them have launched more than 1,000 tons of shipping in a year. The three firms named above construct, between them, more than two-thirds of the total tonnage.

Besides these private establishments, there are four Imperial ship-

IN THE PARK—TOKYO

yards in Japan. The Yokosuka and Kure dockyards have each accommodation for the building of two large battleships or armoured cruisers at a time, while smaller war vessels are constructed by the government at Sasebo and Maizuru. In the last two years the following ships of war have been launched at the Imperial yards:

	Tons	I. H. P.
Aki, turbine battleship	19,800	24,000
Ibuki, turbine cruiser	14,600	27,000
Kurama, cruiser	14,600	22,500
Tone, cruiser	4,100	15,000
Uranami, t. b. d.	380	6,000
Shikinami, t. b. d.	380	6,000

The Japanese engineers claim that they can now complete a first-class battleship in just about two years, so far as hull, engines and armour are concerned; but admit that the provision of gun equipment would take longer, unless imported. The first-class cruiser *Ibuki* was laid down at Kure dockyard on May 22, 1907, and launched on November 21 in the same year—truly a creditable achievement. Nearly all the steel used in the construction of this vessel was supplied by the Imperial works at Wakamatsu. Both the Kure and Yokosuka dockyards are now furnished with every appliance necessary for the rapid handling of materials, and at the former place is the Imperial arsenal, with its armour plate and big gun shops. At the Sasebo dockyard three new dry docks, of 475 feet, 600 feet and 750 feet in length, are just about approaching completion. In design, workmanship and finish Japanese shipbuilding has attained a high status. Our rivals are still somewhat behind in cost and time of production. In speed they will soon be abreast of us, no doubt; but in the matter of cheap productive costs their prospects are not quite so promising.

POWER-PLANT WASTES

By Percival Robert Moses

In the first of the articles by Mr. Moses, appearing in the October issue, some preventable wastes in the use of fuel in power plants were discussed. The present paper takes up the subjects of preventable wastes in labour, in water, and in maintenance. The series will be concluded by a third article devoted to specific examples covering various phases taken from actual practice, and showing the extent to which such losses are actually occurring and the methods by which they are being reduced.—THE EDITOR.

LABOUR WASTES

LABOUR wastes are as numerous as the applications of labour, and as the cost of labour is of either first or second importance among the items making up the total operating cost, it follows that the matter of preventable waste in labour is of prime importance.

Among the causes of preventable labour waste incidental to the general design of the equipment are the excessive sub-division and duplication of the power plant and its piping.

It is advisable to provide sufficient sub-division to allow economical operation, but the widespread idea that it is necessary to have an engine or a boiler exactly of the size required by the load is erroneous. As long as the load is between 50 per cent, and 125 per cent. of the rated capacity the gain by using a smaller or a larger unit is too trifling to warrant the extra expenditure for an additional unit, with its consequent increased fixed and maintenance charges. The extra unit also always involves extra labour for cleaning, oiling, starting and stopping, and for maintenance of piping and valves. Every extra unit involves additional condensation because of extra piping, and additional opportunities are afforded for leaks, concealed and revealed. There is more engine-room floor space to be cleaned and more switchboard apparatus.

In general, therefore, a power plant should be reduced to the fewest units consistent with reasonable economy of operation, and a few pounds of steam theoretically saved by subdivision may be readily sacrificed to save actual dollars' worth of labour, oil, repairs and complication.

The same reasoning applies to the complicated ring and duplex systems of piping, with numerous valves and by-passes designed to insure absolute continuity of operation, and often failing in this purpose completely because of neglect to duplicate some minor part of the system.

It is well to have an auxiliary steam line, in addition to the main steam line, connected to one or more of the large engines and other essential parts of the power plant; but it is not essential or advisable, except in special cases, to have every engine and boiler so connected. Whenever this is done the labour required for the plant is bound to be increased, if only to take care of renewal of gaskets and repairs of valves, traps and connections.

For the small manufacturing establishment, operating ten or eleven hours per day, a single engine and dynamo big enough for the day load, with possibly, but not usually, a small engine and dynamo for light-load periods, will be found sufficiently safe for practical purposes, and the labour for the operation, as well as other costs, will be a minimum. One man usually acts as both engineer and fireman.

For larger plants, sub-division into two or three units is usually advisable, because of a probability of partial operation for extended pe-

riods, and also because of the greater importance of preventing shut-down even for a few hours. In this respect, however, it may be stated that a breakdown of a power plant, operating ten to twelve hours daily, six days a week, with a single unit, is rare, when given intelligent engineering operation and systematic inspection.

Many factory plants in the writer's practice have been in operation six to eight years without shutting down because of breakdown; and even thirteen-story buildings with elevators, etc., are operated in the same manner, placing every dependence on the one engine.

Of course, extra care is involved in such cases, and the possibility is always present of a long shut-down due to smashing of a cylinder head or similar serious mishap.

The spreading over a large area for "show" purposes of the mechanical and electrical equipment is a great labour waster. The more compact the plant the less labour will be required to operate it, and incidentally there will be less condensation and repairs to steam pipes and connections.

Some plant designs show absolute lack of comprehension of the importance of this feature, and separate rooms are provided for pumps, ice machines, compressors and electric plant, extending the piping over an excessive distance and rendering it impossible for one engineer to give the plant proper supervision.

Placing piping or apparatus in places difficult of access, such as underground or in hanging ceilings, or in pits, causes increased labour-cost.

Poor workmanship or material in the original installation passed by faulty inspection involves axiomatically increased labour expense after the plant is accepted.

Frequent offenders in this regard are the boiler setters and pipe fitters, but this will be treated more particularly under maintenance wastes.

In the operation of a plant serious labour waste is prevented by having suitable tools for the work to be done; a man may readily spend a day unsuccessfully trying to do work with a small hammer which could be done in one minute with a sledge, and an engine may be ruined by attempts to make repairs if proper tools are not at hand.

There are but two proper ways to have repairs made, either to have a complete tool equipment and high-grade machinists on the plant itself, if it is big enough, or to have the work done by shops that have such equipment.

Lack of sufficient ventilation in the power plant reduces the efficiency of the labour employed and often causes serious expense.

Two plants come to mind where additional men are needed in the summer (actually they are employed the whole year) merely because of the excessive engine-room temperature—120 degrees to 130 degrees F. during the hot season—and this extra labour is not the most serious matter, as this excessive temperature has caused in one instance such neglect of machinery as to make the installation of a large additional unit necessary.

In connection with the design of the parts of the plant some frequently neglected points may well be noted.

In building steel smokestacks the provision of a ring at the top with hook and tackle makes the labour of painting an easy matter, yet many stacks have no such provision. Provision of doors for easily removing accumulated soot from the connection between the boilers and the stack saves time in cleaning and permits cleaning to be done without shut-down, and costs substantially nothing at the time of making the connection. Similar provision should be made for cleaning out the back connection of boilers. Often, however, the soot, etc., has to be carried out over the bridge wall and grates, merely because of failure to provide for its easier removal.

Insufficient fire-room space, or excessive space, are each labour wasters. The first makes cleaning difficult and the second usually involves extra coal handling.

Automatic feed pump and damper control is now usual and saves labour, but both are frequently omitted. In the design of engines the installation of automatic systems of lubricating and filtering and re-circulating oil is a great time and money-saver, as is also the use of suitable metallic packing.

Indicator rigging permanently installed on the engine and arranged to allow indicator cards to be taken frequently and easily will save labour, and will also unquestionably result in a better maintenance of the initial operating efficiency. Provision for easy starting, such as an internal gear on the fly-wheel, or the compressed air system in use with gas engines, all save labour.

Lack of jack and eye-bolts or of overhead hand cranes often make a day's work out of a job which should need a half-hour or so.

Compressed air for cleaning is a great help, particularly for dynamos and motors and starting boxes. This brings up the dynamo in its relation to labour—spaces catching dust and oil, and hence requiring cleaning out, are an abomination. Sooner or later they will not be cleaned, and trouble will result, and even if this is not the case a great deal of time will be required for cleaning and inspection.

Almost all dynamos and motors have self-oiling bearings, and it is advisable that the oil reservoirs should be provided with gauges showing at a glance the height of oil.

In the design of the wiring system a great amount of time can be saved by the control of groups of lights close to their location. Unsoldered connections and failure to remove "grounds" or electric leaks mean increased labour bills. The use of motor-dynamos instead of batteries for bell systems and similar low-voltage work means an almost unbelievable amount of time and annoyance, saved whenever the system is extensive.

Circuit-breakers on circuits likely to blow fuses save their cost in a short time by the saving in cost of fuses and the labour required to install them, and, what is more important, to be in readiness to install them.

In the handling of coal and ashes and other bulky material the use of mechanical stores and conveyor systems is too well known to need much comment.

For the small factory or plant such systems are usually not installed because of cost and complication of apparatus. For large factories or other buildings they should receive careful consideration, not only because of the money value of the labour directly saved, but because every reduction in the amount of necessary labour brings with it reduction in the difficulty of plant operation.

The installation of a telephone in the engine room, connected to one or more points in the building, is always advisable and often neglected.

Abundant lighting facilities, to allow detailed and careful examination of all parts of the plant, cost but little to install, and may prevent serious trouble. Systematic plant operation is the most important of all labour savers in plants requiring more than one or two men.

By this is meant the assignment of duties to the employees best fitted for the work, so that an engineer receiving $4 a day will not be doing oilers' work worth $1.50 per day. Nor, on the other hand, will the unskilled oiler be permitted to do repair work involving years of machinist training.

Records, similar to a ship's log, should be kept, so that every part of the plant operation is checked, at least hourly, by someone with knowledge.

Inspection blanks, on which is noted the condition of every part of every machine in the plant, should be

filled out carefully once or twice a month, or oftener, if it seems necessary. Such inspections will prevent the continuance of bad conditions, and will allow the proverbial stitch in time to be taken. They will also put the operating men on their mettle and make them take special pains to prevent the continuance of defects or neglects which would be disclosed on the detailed inspection. Duplication of work should be avoided and the helper habit discouraged. Each man should be able to carry out his work alone, without a helper standing alongside to hold a step-ladder or hand up tools. Too great subdivision into departments often causes an unnecessarily large force, as, for example, the division into electrical, plumbing and mechanical departments. It is well to have men specially skilled in each branch; but they should all be under one head, and ready for work in any other branch, if there is more need for them than in their own.

A system of repair blanks is valuable as a means of locating repeated trouble and preventing waste of time. On such blanks is noted the work to be done, the time the order is received, material used, and time required for completion. These orders are delivered by the chief engineer or his representative to the man assigned to the job, and it should be his province to see that the work is rapidly and properly completed, and each blank should receive the chief's O. K. before being filed.

WATER WASTES

Only less important than the fuel and labour wastes are the water wastes. In some plants, notably those for producing refrigeration or manufacturing ice, the cost of water may exceed the cost of fuel. In gas-engine and gas-producer plants the cost of water is a serious item, unless suitable provision is made. In large central-station plants with compound or triple-expansion condensing engines the cost runs up in the tens of thousands of dollars per year for the water wasted as condensed steam only, excluding the water used for condensing this steam, as this is usually river or salt water. In the ordinary private or isolated plant operating condensing, it is customary to avoid this waste and take the oil out of the steam and return as much as possible of the condensed steam to the boilers. In the heating season with non-condensing engines a large part of the water for steam can be saved and re-used, but in the non-heating season not over 20 per cent. can be saved. In the large building of the modern city, or in the large factory obtaining its water from the city mains, the waste of water is a serious thing and worth careful investigation. In such plants water wastes are not confined to the power plant, but extend throughout the building wherever water is used. It is not the province of this discussion to treat all such wastes; in fact, it would be impossible; but such examples occur at once to the mind, as the concealed leaks from water-closet tanks, leakage from underground piping, wastes from distilling apparatus, etc. Returning to the power plant, there is no excuse with the present state of the art for continuing to waste the condensed steam exhausted or delivered by the steam engines and pumps on the ground that the oil cannot be sufficiently removed. This is true whether the steam is condensed by the radiators of the heating system, by coils of drying-rooms, or by a condenser creating a vacuum. Standard grease-extracting devices will, if correctly installed and operated, extract a sufficient percentage of the grease to allow perfectly safe operation. Water wastes due to leaks in valves, traps or joints have been pointed out in the discussion of "Fuel Wastes" in the issue of this magazine for October, 1909, and it may merely be noted here that any steam waste involves water waste, as well as a fuel waste. In connection with the use of water for condens-

ing purposes wastes arrive from several causes. This applies equally to the steam condenser of the engine and the ammonia condenser of the refrigerating machine.

The most frequent defect which causes waste of water is in the design of the circulation. The principle, "That the hottest water should meet the hottest gas," should need no explanation; but it is often overlooked, and in consequence the cold water, meeting the hottest gas, becomes heated and useless for cooling the cooler gas, and additional water has to be introduced.

Besides this defect in design, the failure to use the water heated by cooling the steam or gas, where it may be used without detriment, causes waste. This is frequently found in the design of water circulation for gas engines and producers. The water used to cool the cylinder may be afterwards used in other parts of the apparatus, and a double use of water obtained, as well as a saving of the heat otherwise carried away. If this jacket water, still further heated by the exhaust gases of the engines, is used for heating the building, either directly or indirectly, and is re-circulated, a still greater economy in the water-use is obtained. Failure to provide sufficient heat-transfer surface in condensers is another waster of water, and the result is similar to the poor design of the circulating system; that is, the water goes out without having done all the work it is capable of doing. Failure to save the water from condensers is a flagrant but, unfortunately, a frequent waste; sometimes it is a fancied contamination; at other times insufficient storage capacity is provided to allow for the varying demand from the building and supply from the condenser; and again, ignorance of the quantity wasted and of the possibility of saving allow the water to run to waste. Such waste is sometimes unavoidable; but a large storage capacity, intelligently operated as a reservoir, filling up when the demand is light, will usually effect a saving paying a large return on the investment. Failure to provide for cooling and re-circulating water used for condensing purposes is a usual form of avoidable waste. Cooling apparatus is more or less expensive, depending upon the extent of the cooling desired and local conditions; but wherever water is purchased at 50 cents or more per 1,000 cubic feet, a cooling and re-circulating plant will be found advisable, and often where a lower-price water is obtainable. The operation of the plant has a good deal to do with the amount of water used, as even with the best design of a circulating system water can still be allowed to flow out cold to the sewer, and if leaks are not checked or returns are wasted no planning beforehand will prevent loss. There is but one way of checking such waste—systematic records and comparison with results obtained by others. Every operator has a "good" reason why he does not do as "others" do; but careful comparison of conditions will often show that the reason is not based on solid foundation, and what the "others" do cannot be done by the "one."

WASTES IN THE MAINTENANCE OF MACHINERY

While it is true that all wastes due to excessive maintenance expense are partly wastes of labour and should be covered under this division, the subject of maintenance is treated here separately, because the amount of these wastes will depend largely upon the original design, and their prevention is an easy matter if it is undertaken while the plant is in the planning stage.

If the wastes are to be cured after the original design has solidified into brick, mortar and iron, the expense of the cure is frequently found to be so great as to make it impracticable.

From the writer's own early mistakes many instances could be pointed out where preventable wastes in maintenance still exist, due to defects in

design and lack of sufficient practical operating experience.

For example, take the case of the building of two boilers in a boiler setting with only a 14-inch wall between the fires. These boilers were situated in a confined pit under the sidewalk vault, and every five years or so a boiler has to be placed in the street while the middle wall is being rebuilt. Correction is now impossible, as all the rest of the building space is occupied; yet how easy it would have been originally to change the dimensions of the boilers in order to get an 18-inch wall, at least, between!

Preventable wastes occur in connection with the maintenance of boilers through poor workmanship on the settings, such as the failure to use very thin fire clay and to rub the firebricks to a close joint; or the use of inferior material; failure to allow sufficient elasticity for the expansion; failure to set the water gauges and connections properly; failure to provide manholes for easy access under and above the tubes on horizontal return-tubular boilers.

In the construction of grates whole installations have warped and become useless through failure to provide for the latitudinal expansion of the bearing bars. This expansion warped the bearing bars and prevented the grates from falling to their proper position, and in a short time half the sections were burned off at their tips. Poor mason work and supervision cost the purchaser $450, and saved nobody anything except a little time. Insufficient height to the ash pit may cause similar trouble. In the Sterling type of water-tube boiler a great many tube failures have been caused by neglecting to allow sufficient space between the grates and the first row of tubes. In all types of boilers insufficient provision for cleaning inside and outside will show up in dollars and cents in a short time.

Steam piping is, perhaps, the most frequent sufferer from poor design. The largest department store in New York City had to take down its whole steam main and re-install it, because of trouble all over the line with leaks; and the largest apartment house in New York City had a similar experience—a long line of 12-inch pipe was put up with screwed joints instead of extra heavy flanged joints, and leaks started at one or two of these screwed joints. They were calked, but soon started again, and, as it was impossible to screw up one joint without taking down the whole line, the leaks gradually got worse and worse until the whole cellar was filled with escaping steam. Finally an auxiliary line was run and the old line taken down and put up again with flanged joints and the trouble cured, but at a cost of nearly $20,000, and the original saving (?) was probably a few hundred dollars at the most.

In connection with this same plant the failure to provide some means of partially operating the system, at least while needed repairs were made, was emphasized. Usually this provision consists of an auxiliary steam pipe; but where everything is electrically driven, a storage battery or a street connection may better serve the purpose.

Insufficient allowance for expansion in piping is costly. The writer has seen every connection along a long line of pipe snap off like threads when steam was first turned on, because of poor design, and even when such an extreme case does not occur the leaking of gaskets and joints indicates the undue strain.

Bends are the most satisfactory way of providing for expansion, although on long lines of low-pressure pipe, where bends are not possible, properly designed expansion joints serve the purpose.

Failure to insure the removal of the condensed steam from the pipes will invariably cause trouble and repair, and such provision should be made as nearly fool-proof as possible. The location of piping, particu-

larly with respect to joints, in exposed positions, is a frequent cause of excessive maintenance cost. In placing piping under the floor there are hundreds of cases in which the pipes are imbedded in ash concrete, and in several instances these pipes have been eaten out and replaced, and eaten out again, without apparently impressing the fact upon the purchaser that it is a poor policy to put pipes underground at all; but if it has to be done, the pipes should by all means be kept free from contact with surrounding material.

Where extremely hot water has to be pumped, as in the case of boiler feeding, it is poor economy to put in standard weight wrought-iron pipe, and only slightly better judgment to use extra heavy pipe, as both will pit out in time. Brass or copper pipe seems to last indefinitely, and as the labour of installation is the largest part of the cost, the material that will last the longest should be used. This is also advisable from the viewpoint of continued safety in operation, as a number of serious accidents have occurred from the bursting of feed pipes, with the ensuing discharge of boiling water through the short lengths of pipe between boiler and check valve. Gasket renewals are a constant source of annoyance and expense, and no one type of gasket is best for all locations and conditions; other people's experience must be obtained, and if care is taken in this small item a great deal of subsequent trouble and waste may be prevented. The use of valves with renewable discs for radiators has become so general as hardly to need direction of attention to the fact that such discs minimize maintenance in this factor; but the discs should be heavy and provided with a spring or loose backing, so that the disc may adjust itself to the seat and not check.

As a general proposition, the use of poor material may be stated as constituting a cause of preventable wastes; but it should be noted in this connection that the installation of extra heavy valves and fittings for low-pressure work, or of boilers capable of standing 150 pounds pressure in a steam-heating job, are equally poor engineering, causing incurable wastes, because the losses are in the form of fixed charges on the investment.

(To be concluded.)

MACHINE TOOL DESIGN

MODERN BRITISH PRACTICE

By Fred. Coxon

TWENTY-FIVE years ago the machine tool business was, perhaps, the least scientific of any of the mechanical engineering trades. Such merit as there was depended a great deal more on accuracy and workmanship than upon scientific design. Rule of thumb, with a minimum of calculation, was the order of the day. Little or no attempt was made to examine or analyse the conditions under which a metal-cutting tool performed its work. Such a thing as a guarantee of output by a machine tool builder was rare. Catalogues of machinery made vague claims as to "powerful gearing," "massive bed plates," etc., etc., but rarely gave figures as to ability to produce chips. In the application of a given amount of material to the performance of particular work, a crane maker was a very much more scientific and responsible man than a machine tool maker.

Outside of the half dozen or so firms of repute engaged in the machine tool business twenty-five years ago (speaking of Great Britain) the rank and file were more or less copyists. They were not expected, and did not try, to get away from or improve upon the then standard designs. They did not want responsibility, and were rarely entrusted with it. Amongst the leading firms, design was at a standstill, and it was not until the American invasior of the late eighties and nineties that things began to wake up.

It is not the writer's intention to claim that the machine tool trade has now attained an equal scientific excellence with steam engineering, but he will try to show that in the past quarter of a century immense strides have been made, and that to-day the machine tool maker uses his materials with a fairly accurate fore-knowledge of the results he will obtain.

Turning to some of the old machine tool catalogues of the "eighties" we find that, generally speaking, each maker built all kinds or most kinds of tool. He could produce and supply a whole machine shop plant. This system was clearly opposed to scientific advancement, for the interests of designers were spread over the whole range of machine tools, and only by steady devotion to a few lines can the best results be obtained. There were few machine tool shops twenty-five years ago which employed more than 300 men, so that the separation of the staff into departments, each dealing with a special line, was impossible. Draftsmen, machine hands and fitters were rarely employed on two similar jobs consecutively. Thus not only was design at that period in a very crude state, but the cost of production was naturally high. Special workshop appliances, such as boring jigs, could only be used in a limited way, and neither workpeople nor plant could be specialized under the existing conditions. The idea of "manufacturing" as opposed to "building," although well understood in many mechanical trades, was practically absent from the machine tool business.

The change was to come from America. Messrs. Brown & Sharpe, Messrs. Brainards, Messrs. Sellers,

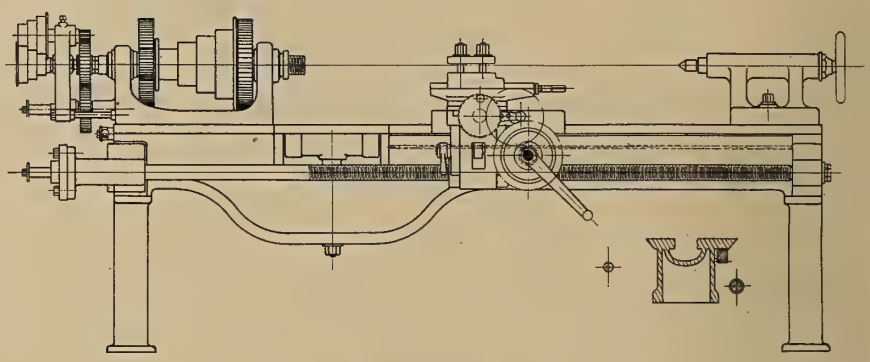


FIG. 1.—OLD-TIME LATHE

and other firms sent machinery and tools to England which were obviously far more advanced and developed than British lines were. The involute gear cutter and the twist drill were exceedingly important influences, and quickly made their mark on the trade. The grinding machine for cylindrical work, and the micrometer calliper, at once found appreciation and took up a rightful and unassailable position in machine shops. It is not claimed that all or any of these mechanical devices originated in the United States, but the credit of their development and perfection belongs unquestionably to America. The bicycle boom and general trade revival of the early nineties was America's opportunity. With the English machine tool trade unready and asleep, America was enabled to pour into Great Britain a flood of machine tools, mostly of great merit. By this time America's machine tool trade had made marvelous progress in the direction of specialization. The manufacturers of Cincinnati and the Middle West had put down plants of the very latest machinery, with highly organized shop system, and each strictly confining his business to one line of goods, had been able to turn out machine tools which were wonders of mechanical perfection and low cost. British machine tool makers (I am speaking rather of small and medium-size machine tools than of the heavier ones) were for a time outclassed. This state of things did not last long, however, the introduction of high-speed steels, the rapid growth of the automobile industry and other stimulating influences, not least of which was the spirit of rivalry, soon brought the British tool makers into line. Conservative as he is supposed to be, the English engineer took hold of and applied the high-speed steels to his work quicker and more generally in this country than did the American engineer. The tool maker was quick to grasp the requirements, and to-day the machine tool industry of this country is second to none. Such

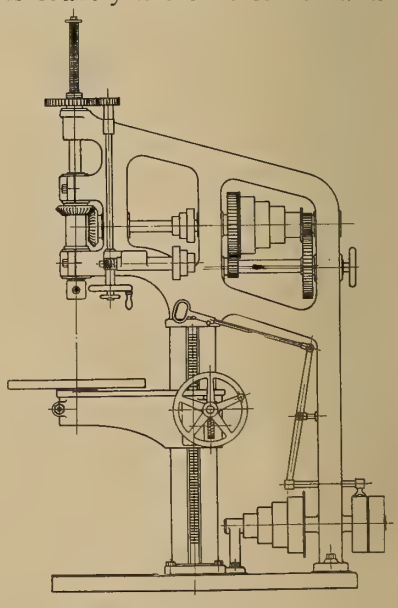


FIG. 2.—OLD-TYPE DRILLING MACHINE

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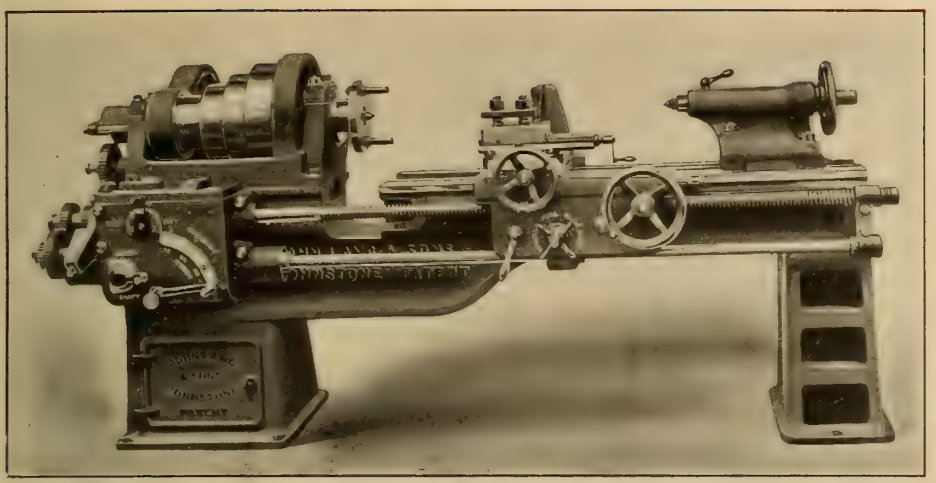


FIG. 3.—8-INCH CENTRE SLIDING, SURFACING AND SCREW-CUTTING LATHE. JOHN LANG & SONS, JOHNSTONE

is the writer's impression of the machine tool history of the last twenty-five years or so.

One of the most striking features of the up-to-date machine tool is its complication. Cost has been very largely increased, but not in proportion to the greater amount of work in the finished machine, because makers have specialized more, and now manufacture in larger quantities.

Recognizing that design has a tendency to follow fashion, which a maker of repute is in a position to set, we must admit that many of the popular features of modern tools may possibly have no complete justification and will, perhaps, be eliminated in the course of time. It is the business of the machine tool man to analyze the conditions which will justify, or otherwise, every feature of his work, although temporary competition may force him to manufacture something which he more than suspects to be a mere passing fashion.

So far the actual efficiency of a machine tool as a power transmitter has never been a matter of very serious consideration. Machine tool buyers of to-day are anxious enough about the output of their tools, but do not concern themselves so much with the power which they put into their machinery. Probably this is due to the fact that power cost in a machine shop is a comparatively small item. I do not fancy machine tool builders will be anxious to force this point to the front, anyhow. Of course, there is a definite relationship between the amount of power consumed and the amount of chips produced in every metal-cutting operation, but the power wasted in friction of the machine or with bad cutting conditions of the tool may be in some cases a startling amount.

Chief amongst the costly features of modern tools are what are known

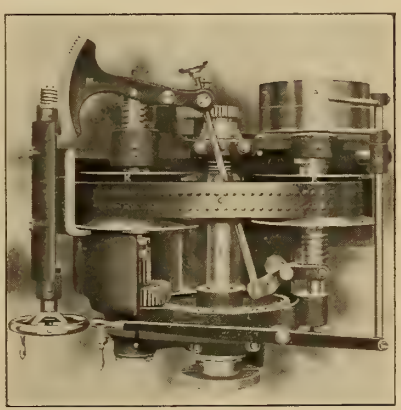


FIG. 4.—VARIABLE-SPEED GEAR. JOHN LANG & SONS, JOHNSTONE

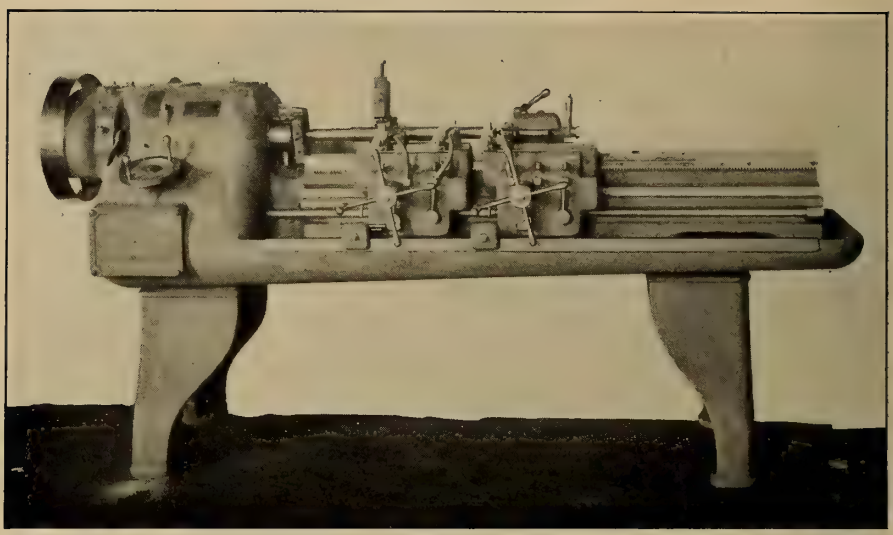


FIG. 5.—THE LO-SWING LATHE. FITCHBURG MACHINE CO., FITCHBURG, U. S. A.

as change-speed boxes or single-pulley drives and change-feed boxes. These devices provide a number of changes of speed or feed, and have means of more or less quickly changing. The aim is to enable the operator to obtain, with small loss of time, the nearest to the maximum cutting rate which his work will permit. The value of such devices depends largely upon the frequency of the changes required on any one piece of work, or on the variety of work any particular machine is called upon to handle. It must be borne in mind that the general trend of manufacture is towards specialization and standardization, which seems to point to the probability that the range of work any one tool is required to deal with will decrease rather than increase. Taking the

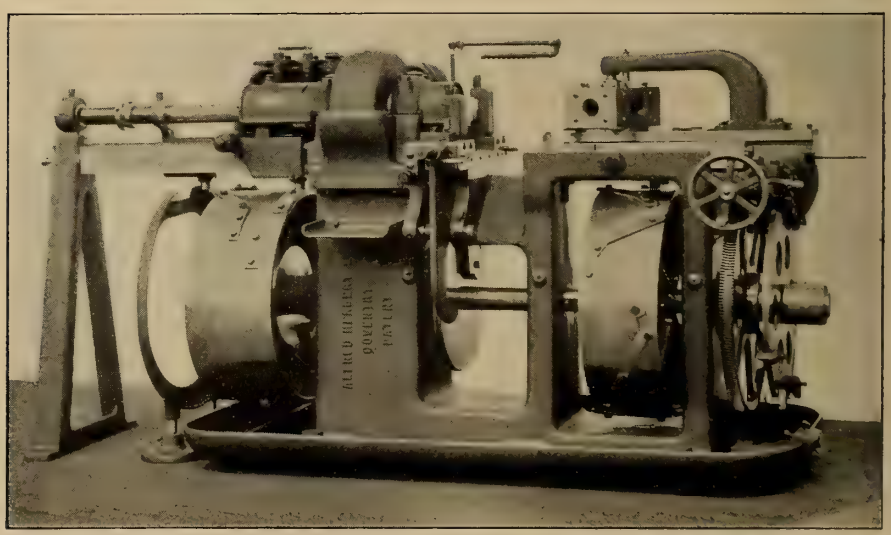


FIG. 6.—AUTOMATIC CAPSTAN LATHE. ALFRED HERBERT, LTD., COVENTRY

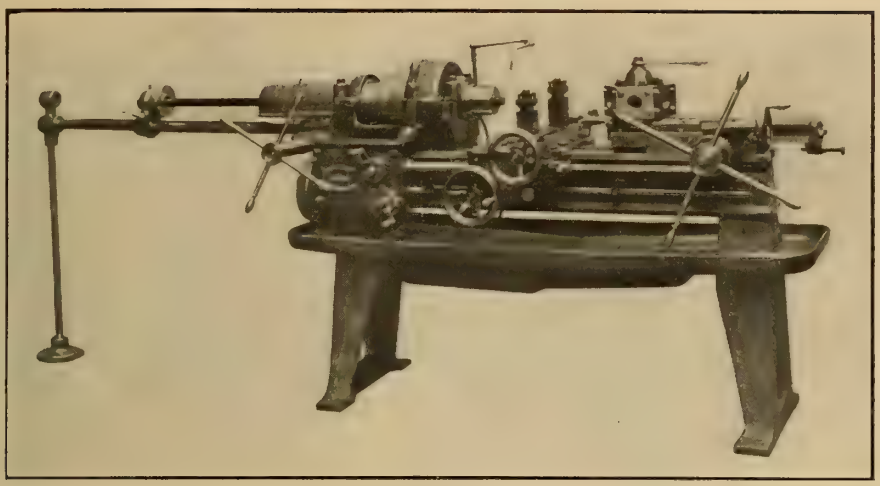


FIG. 7.—CAPSTAN LATHE. H. W. WARD & CO., BIRMINGHAM

engine lathe first: Fig. 1 shows a typical English lathe of twenty-five years ago. The small cone pulley and the narrow bed strike one as curious features compared with modern practice. The guide screw was at the front with its own separate train of gearing, and the feed shaft for sliding and surfacing was at the back and driven by cone pulleys. All the gears had cast teeth. Compare it with its modern successor, Fig. 3, built by Messrs. Lang & Co., of Johnstone. Here the cone pulley is wide, and as large in diameter as can be got in the headstock.

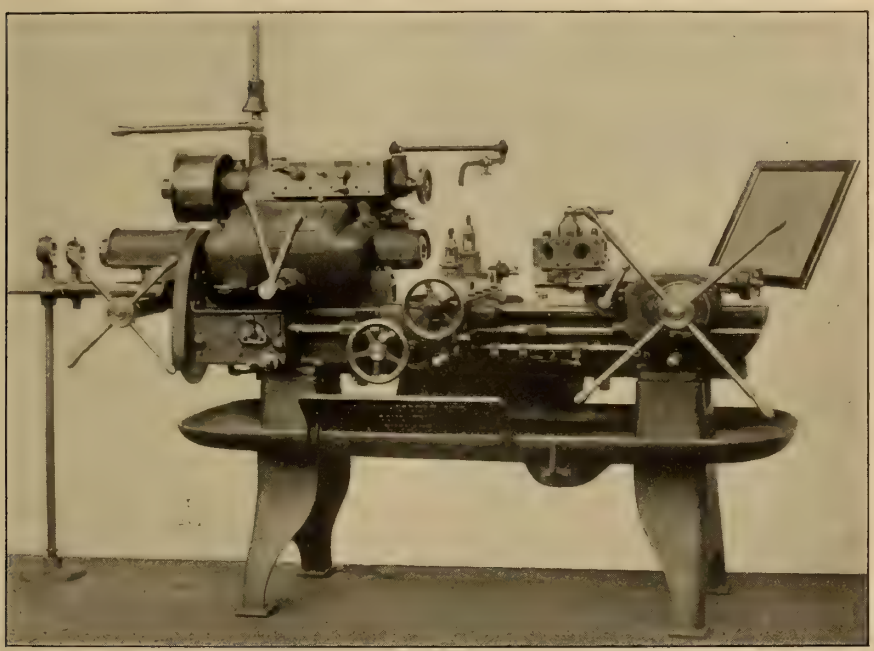


FIG. 8.—AUTOMATIC CAPSTAN LATHE. ALFRED HERBERT, LTD., COVENTRY

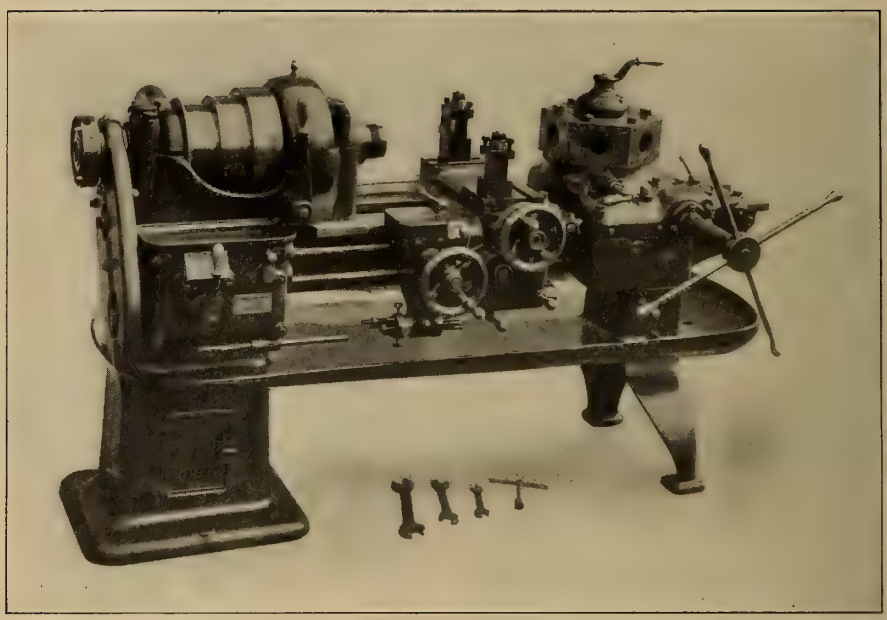


FIG. 9.—CAPSTAN LATHE WITH CHASING SADDLE. CENTAUR MOTOR & ENGINEERING CO., COVENTRY

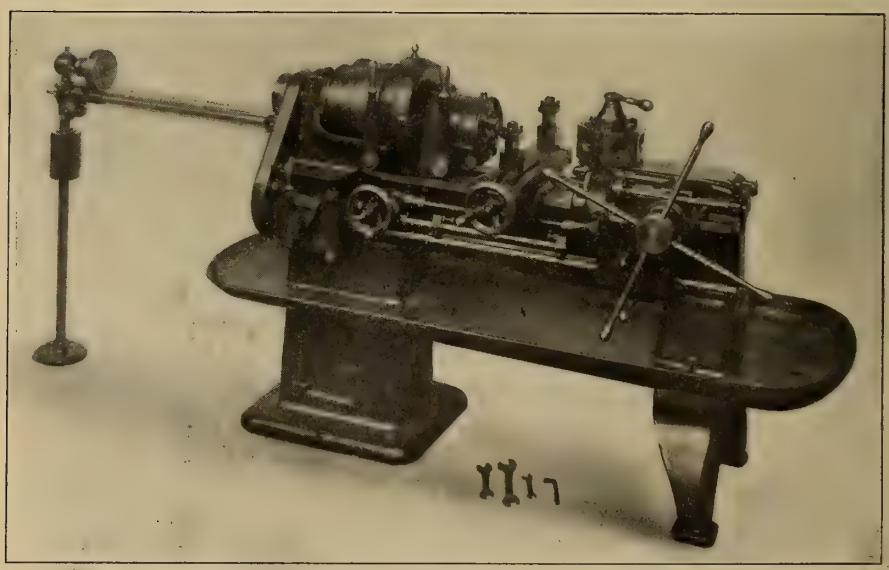


FIG. 10.—6½-INCH CAPSTAN LATHE. CENTAUR MOTOR & ENGINEERING CO., COVENTRY

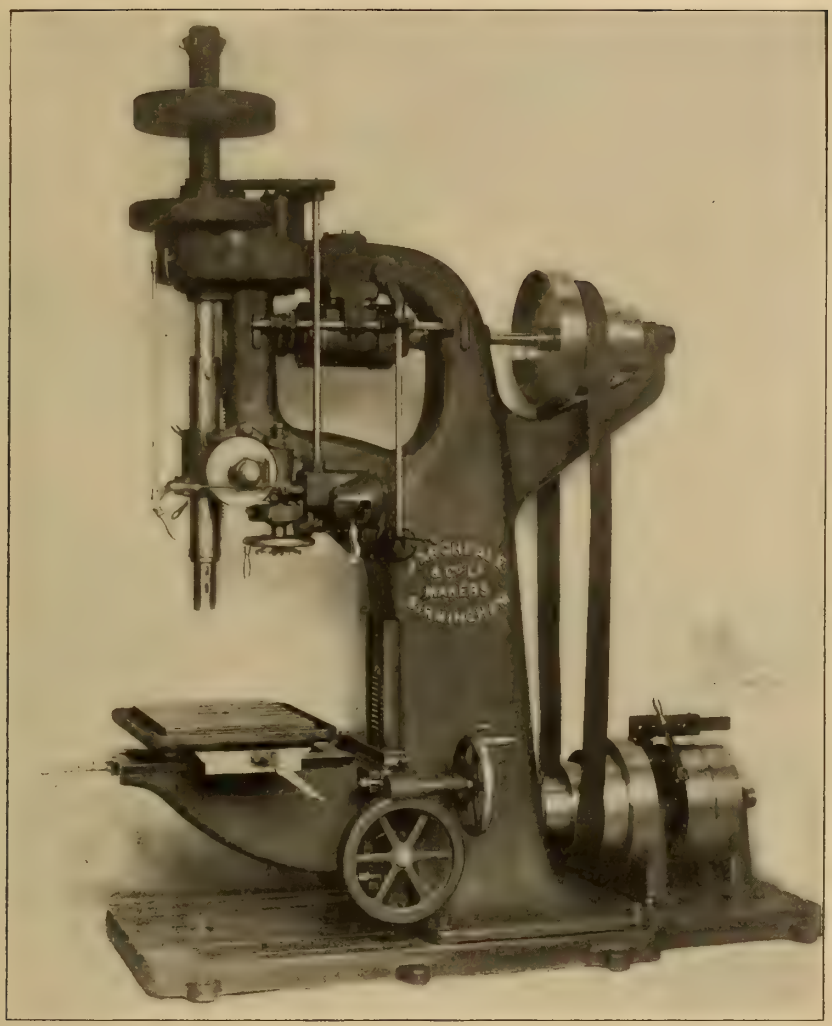


FIG. 11.—VERTICAL DRILLING MACHINE. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

Both feed shaft and guide screw are at the front and are governed by one "feed box," so that four rates of feed and four pitches of thread can be cut without shifting belts or gears, the changes being made by lever movements. The feed shaft being at the front of lathe leaves the back clear for a handy and useful taper attachment. The output of the modern lathe is from two to three times that of the older type, this result being due to the ability to withstand greater stress at higher speeds and to the positively-geared feeds, as well as to the greater facility with which changes of feed can be made.

What is known as the "single-pulley headstock" has become a common feature of the engine lathe. The single-driving pulley delivers a constant amount of power into the headstock, the changes of speed being made by friction or tooth clutches or sliding gears.

A special and patented form of single-pulley head-stock is that made

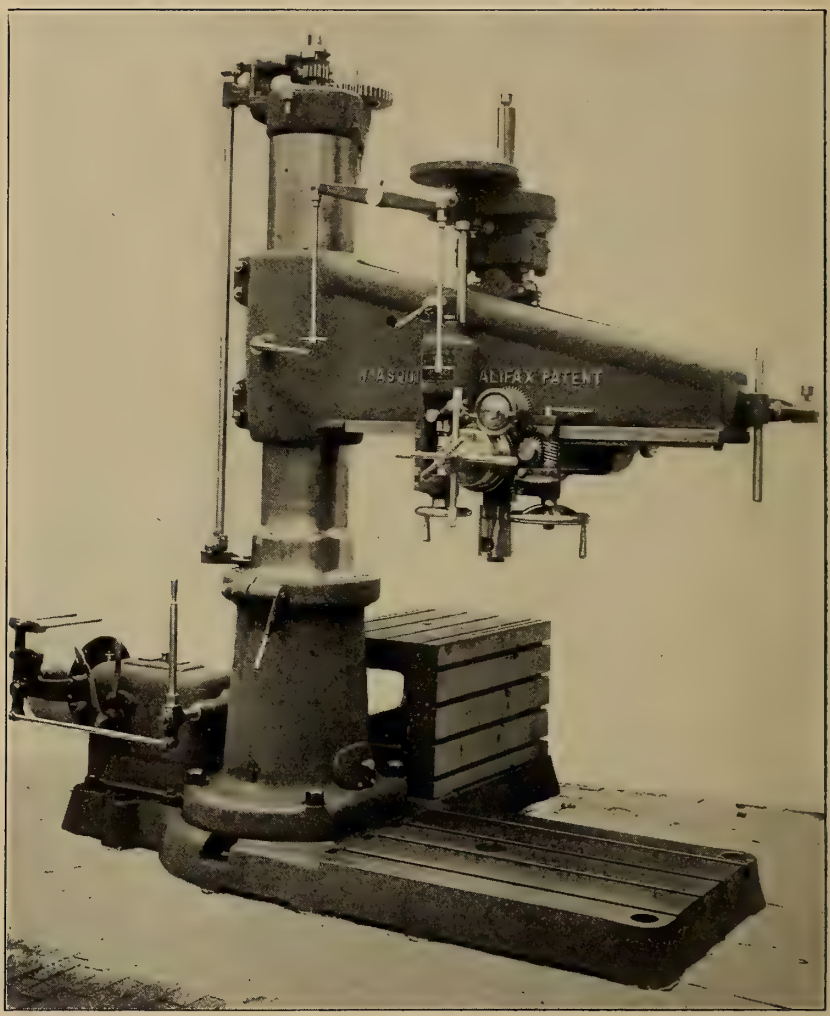


FIG. 12.—CENTRAL THRUST, RADIAL DRILLING MACHINE. WM. ASQUITH, LTD., HALIFAX

by Messrs. Lang, and shown in Fig. 4. Roughly, the device consists of a special belt of Vee section and pulleys, each of which consists of two discs which have beveled faces between which the belt works, the driving effect being on the sides of the Vee belt. Means are provided by which the two discs which form the driving pulley are made to approach each other, or to recede from each other, thus altering the effective diameter of the driving pulley. A similar alteration, but in the opposite direction, simultaneously takes place in the driven pulley. Thus the device is capable of giving an infinite gradation of speed within its limits, as opposed to the stepped speeds, produced by cone pulleys or toothed gearing. On their boring and surfacing lathes Messrs. Lang have provided means of automatically altering the speed while surfacing, the cross-slide of the lathe being geared up to the change-speed device just described, so that as the tool approaches the centre of the work the speed is automatically increased. The shop cost of work

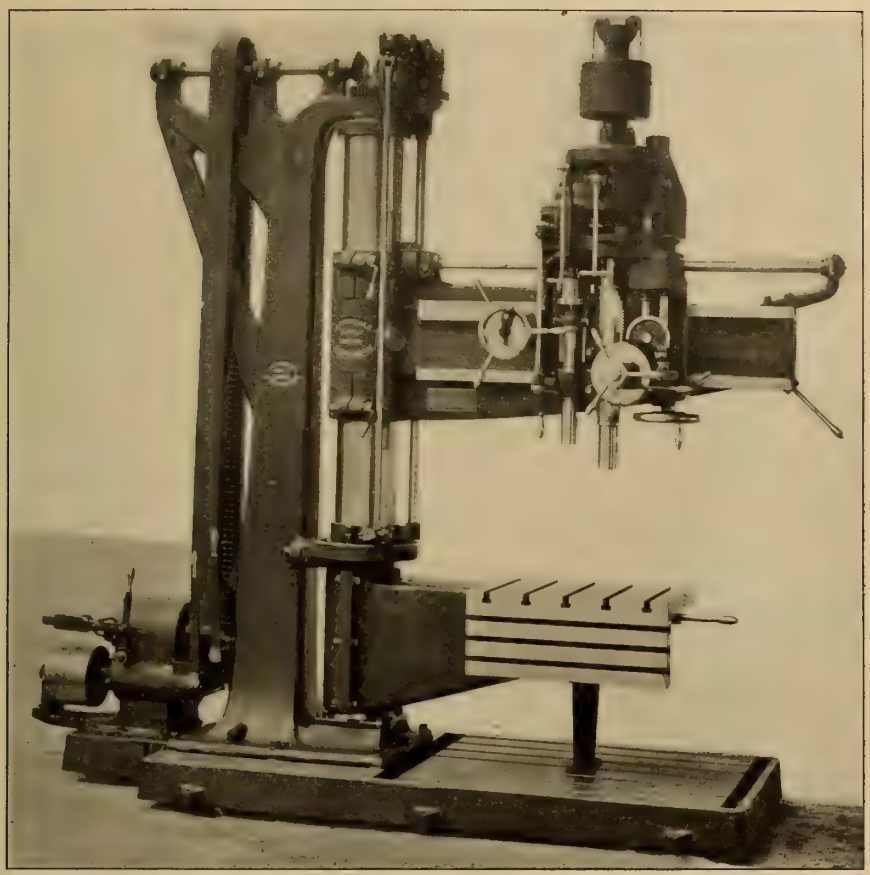


FIG. 13.—RADIAL DRILLING MACHINE WITH EXTRA SPINDLE FOR TAPPING. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

which has face turning to be done may be reduced considerably by this means.

The range of work which can be dealt with in an ordinary lathe is very great. Most English lathes are fitted with a gap for large diameter chuck and face plate work. Americans have never taken kindly to this feature, few makers offering a lathe having a gap. Messrs. J. J. McCabe, of New York, make a lathe having a second spindle, higher and at the back of the ordinary spindle. A second tailstock spindle is also provided. This arrangement has this advantage over the gap lathe, that occasional big work can be dealt with of the full length between centres, whereas the gap will only admit short pieces of work. In contrast to lathes having a gap, or an extra spindle, which are devices for increasing the capacity of the machine, the "Lo Swing" lathe, illustrated in Fig. 5, has been designed with the view of limiting the range of work to be handled. This lathe only deals with work of small diameter carried upon centres. To compensate for its limited range, the Lo Swing lathe offers a greatly increased efficiency on its own class of work. There seems little reason to doubt that this limiting of the range of work that a tool will operate upon, giving greater output and efficiency within its own capacity, is likely to find a growing appreciation.

An immense growth has taken

place in the demand for capstan lathes. In this class of tool the aim is to perform a number of operations on one piece of work without resetting the work or tools. Provision is made for carrying a large number of tools, each of which can be brought into working position easily and quickly. Where possible, two or more tools may cut simultaneously. On the capstan lathe, quick change of speed and feed are obviously of great value, and one can only predict a continued demand and development in this line of machinery.

In the production of work in large quantities, automatic capstan lathes, a group of which may be attended by one operator, are largely and profitably used. For work that can be suitably produced from the bar, such a machine as we illustrate in Fig. 6, by Messrs. Herbert, of Coventry, is representative of the very latest practice. The production of work from the bar, however, in some cases compares unfavourably in the matter of shop cost with the finishing of stampings or castings. There is no profit in the mere making of chips, and where the finished article weighs only a small proportion of what a blank cylindrical piece large enough to make it would weigh, there is, in most cases, a decided advantage in using castings or forgings. To meet this requirement, "magazine" feeds have been designed for application to auto matic capstan lathes.

What was a decided innovation in the nineties was the Hartness flat turret lathe. In the original form it was chiefly intended to deal with work from the bar. The latest design of the Hartness lathe has been arranged to give special facilities for dealing with chucked work as well as with work from the bar. Here is a case where an increased range of work has been sought for. The cross-traverse headstock of the latest Hartness lathe was an exceedingly bold move, which had at the back of it the excellent reputation which the original Hartness lathe had acquired, and which has since been maintained.

The lathe illustrated in Fig. 8 by Messrs. Herbert fairly represents the very high development which capstan lathes have attained in England. Instantaneous change of speed and feed are provided for. The saddle which carries the cross-slide has a patented chasing arrangement, by which, when thread cutting, the tool and guide nut are withdrawn simultaneously by simple lever movement. Everything about the design tends to make the operator's task easy and his output large.

Briefly referring to the cylindrical grinding machine, which has become the finisher to the lathe man's work, and has superseded the emery clamps and the file for finishing turned work, we have already acknowledged our debt to America for the development of these important additions to our plants. Messrs. Brown & Sharpe, Messrs. Landis and Messrs. Norton, have each contributed largely to our knowledge of this branch of machine-shop practice. For finishing work to accurate dimensions, cylindrical grinding machines have become matters of necessity. A few years ago claims were made for grinding machines as to their capacity for roughing out work as well as for finishing. The emery wheel, however, with its infinite number of very inefficient cutting teeth (inefficient compared with steel cutters), can never take a prominent place as a roughing tool.

After the lathe the drilling machine, perhaps, is of the next importance in machine shops. Going back 25 years and studying the drilling machines of that period (a typical tool illustrated in Fig. 2), one wonders what the drilling-machine operator did with his spare time.

Considerable time would be occupied in winding his drill into position, and also in winding it back

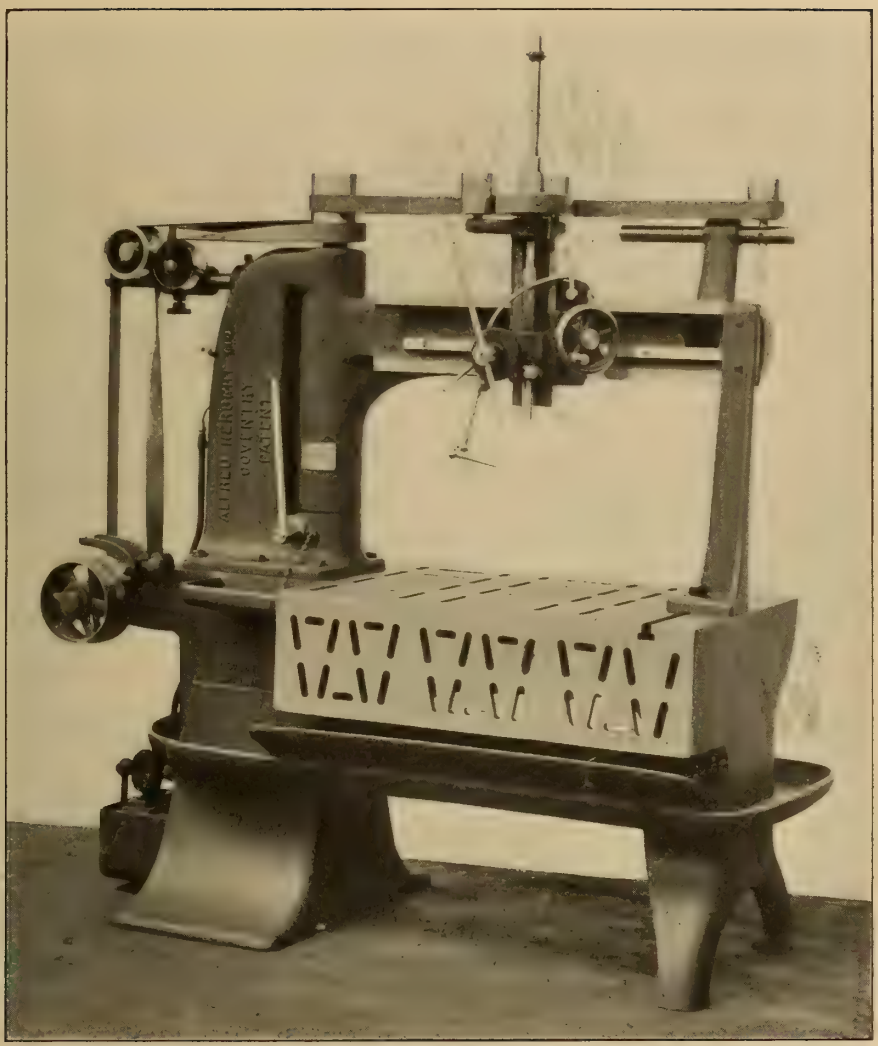


FIG. 14.—SENSITIVE RADIAL DRILLING MACHINE WITH BALL-BEARING SPINDLE. ALFRED HERBERT, LTD., COVENTRY

after drilling, but, when drilling at the rate of 1/3 of an inch per minute, which was about the rate for a 1½-inch drill in cast iron, time must have hung heavily on his hands. One pair only of the steps of the feed-cone pulleys was brightened by the feed belt, and that pair usually gave the slowest feed. The machine illustrated in Fig. 11, by Messrs. Archdale & Co., is the modern successor to the last machine. It will drill 1½-inch diameter hole in cast iron at 5 inches per minute. Six rates of feed are available, instantly changeable, and the drill is withdrawn from the work instantly by star wheel. An instantaneous clutch is provided for starting and stopping the self-acting feed. The machine combines drilling power and handiness to a remarkable degree compared with the older type of machine.

The radial drilling machine has found a steadily increasing demand

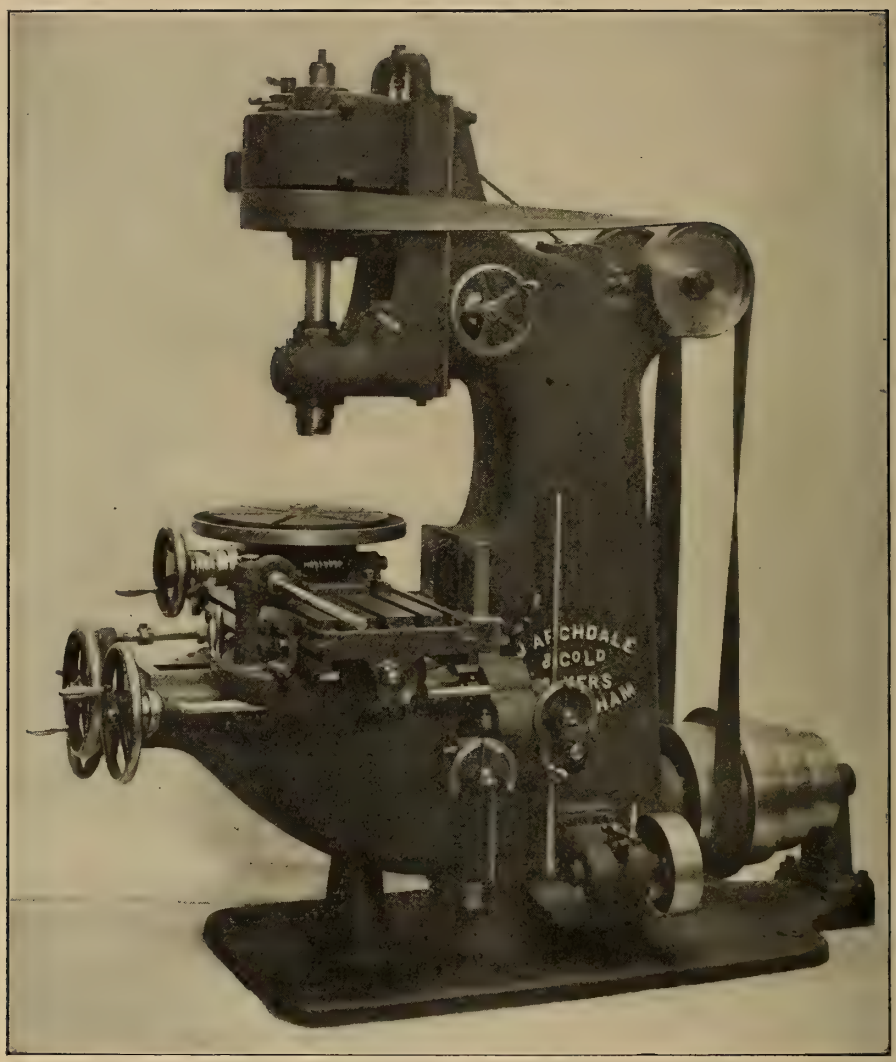


FIG. 16.—VERTICAL MILLING MACHINE. J. ARCHDALE & CO., LTD., BIRMINGHAM

in the last few years. Its great capacity and handiness have obtained for it a leading position amongst machine tools. There is a case where wide range and capacity are called for, and, so far as human foresight can tell, will continue to be called for. For castings of medium or large size having a number of drilling or boring operations to be performed on them, and having holes or faces to be cut of varying size, will, so far as we can see, always be in existence for the radial drill (or its successor) to deal with. Each operation, too, is of comparatively short duration, so that quick-change speed and feed devices are justified in the radial drill as in perhaps no other tool. In "constructional" work a simpler form of radial drill is demanded, for many holes of one size have to be drilled, while the dimensions of the pieces to be drilled do not vary so much as in the case of engineering work. One of the very latest forms of radial drill is illustrated in Fig. 12

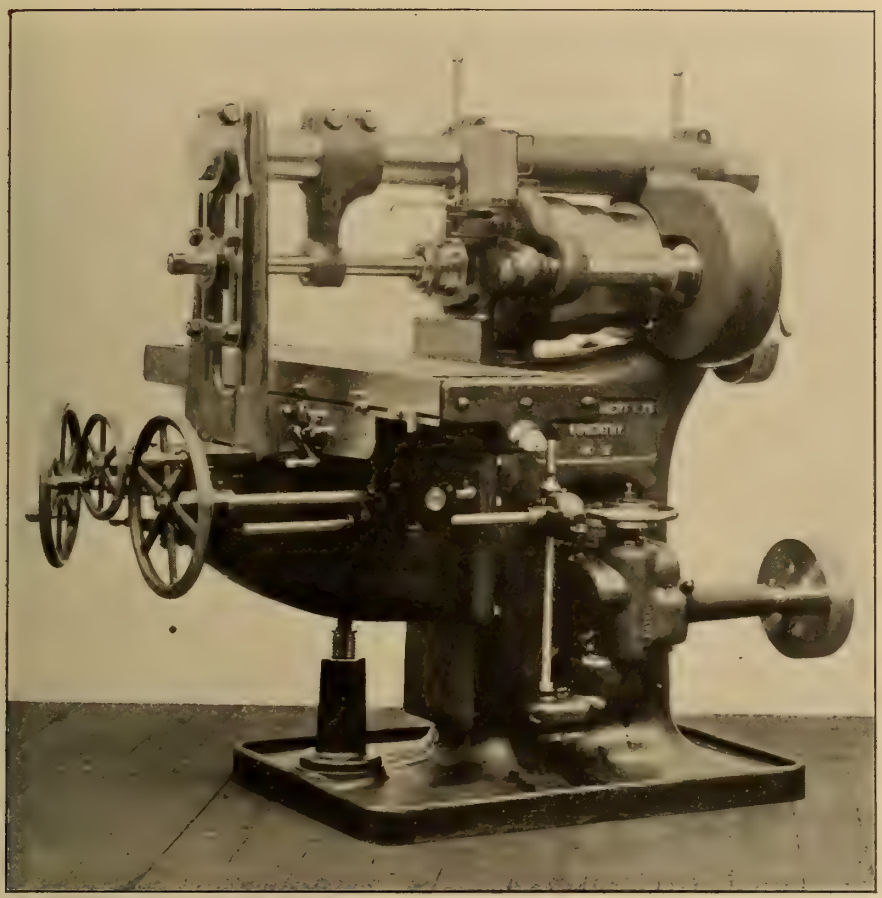


FIG. 17.—HORIZONTAL MILLING MACHINE. ALFRED HERBERT, LTD., COVENTRY

by Messrs. Wm. Asquith, Ltd. As will be seen, it presents some novel and striking features. The "central thrust" arm is obviously well adapted for its work. Everything is arranged to give the best facilities for changing speed and feed, and to make the manipulation of the machine easy and quick.

In Fig. 13 we show one of Messrs. Jas. Archdale's modern radial drills. The most prominent features in this design are the reinforced column and the extra spindle for tapping. The latter is arranged to run at a suitable speed for tapping, and may easily and quickly be moved into exact position over the hole previously drilled. This machine also possesses a large number of feeds and speeds, all of which may be easily and quickly changed. Messrs. Bickford, of Cincinnati, Ohio, U. S. A., make lines of radial drills of exceptionally high merit, and have helped largely in the development of this class of tool. For drilling small holes, the machine shown at Fig. 14 by Messrs. Alfred Herbert is extremely useful and efficient. The spindle is fitted with ball bearings and can be run at a speed of 2,050 revolutions per minute. The makers have been able to get some extraordinary drilling rates from this machine, and largely attribute this to the ball-bearing spindle. Note the complete arrangements for supplying lubricant to the drill and for catching and returning to the pump.

Turning to milling machines, we have a class of tool the cutters for which are comparatively expensive. To change from one cutter to another takes considerable time, as compared with changing a drill or a lathe tool. Milling operations, as a rule, are of fairly long duration, so that the percentage of time saved by quick changes of feed or speed is not so great as in the case of most lathe or drilling operations. Fig. 16 shows a machine of the vertical type by Messrs. Archdale & Co. of recent design. It has eight spindle speeds and eighteen rates of feed. The table has automatic feeds and knock-off motions in two horizontal directions. A detachable circular table, also with automatic feed, is provided. The designer has aimed to get a maximum of rigidity and capacity for producing chips.

The horizontal type of milling machine of the present day is well represented by Fig. 17. In this machine the makers, Messrs. Alfred Herbert, have a patented "dial" feed motion, which enables the operator to obtain any of the sixteen available feeds by the simple rotation of a hand wheel, a pointer indicating the rate obtained.

The old controversy as to whether milling-machine feeds should be driven from the machine spindle or from a countershaft is still unsettled. The advantage of having the rate of feed unaffected by and independent of the spindle speed appeals to many users; while the possibility of the spindle belt slipping while the feed continues, and so doing great damage, deters others from using the independently driven feed motion. In the machine last referred to the makers offer as alternatives either forms of feed motion. Another prominent maker has adopted a system of driving the feed motion of their horizontal milling machines from the headstock cone pulley, so that putting in or out of action the double gearing does not affect the rate of feed, while, if the main belt slips, the feed motion stops.

Space will only permit a brief reference to planing machines. The high-speed problem in planers is beset with peculiar difficulty, owing to their reciprocating action. English makers, notably Messrs. Bateman and Messrs. Redman, both of Yorkshire, have made great advances, but in many machine shops the planing department is still barely able to keep pace with other departments. In the allotted limits of this article, we have only been able to consider in a very general way the most important kinds of metal-cutting tools. The purpose has been to review the recent history and development of machine-tool design, and to throw out suggestions as to future possibilities. Amongst the various stimulating influences on the machine-tool trade, we have to acknowledge our great indebtedness to the Nicholson experiments of 1904. The "dynamometer on the tool post" meant a great deal and was one of the most important messages the machine-tool trade had received in the new century. Undertaken in the interests of high-speed tool steel, and not directly in the interests of machine tools, yet it is emphasized in a very effective way that the machine-tool maker should be responsible for the output of his products.

Nowadays leading machine-tool makers spend a great deal of money in elaborate tests, and every metal-cutting operation has its "horse-power chips" equation. As we have previously hinted, there may be a serious margin still to be dealt with between the power taken into the machine and the power given out on the cutting tool. It is difficult to see how much farther ingenuity can go in the matter of providing quick-speed and feed changes, although the ideal of an efficient infinitely variable gear, suitable for both speeds and feeds, still tempts the designer. We have apparently exhausted the possibilities in stepped changes of speed and feed, and the trade is looking for an innovation.

THE MEASUREMENT OF HUMIDITY

By Samuel K. Patteson

THE question of the amount of moisture present in the atmosphere, its variation under different conditions of temperature and pressure and its effect upon the efficiency of various engineering processes is one that is daily becoming more important to a constantly increasing number of engineers in a considerable variety of engineering developments. Thus it is known to-day that the moisture in the atmosphere affects unfavorably the action of almost every engineering device in which the atmosphere enters as a factor in its operation or design. The gas engine is affected very greatly in its action by the presence of moisture in variable amounts in the atmosphere, and in special developments of this type, such as the automobile engine, where the control of the charge is often inadequate and the load variable, the effect is often sufficient to temporarily swamp the engine. The same effect is also present in small marine engines with even more pronounced significance, and its effect is also present in all internal combustion motor installations. Again, cooling towers depend for their efficient action almost entirely upon the amount of moisture present in the atmosphere, and under some conditions of great humidity their effective action is often almost completely stopped. The presence of moisture in the blast in iron furnace operation has long been known to be the chief variable quantity in its effect on the character and uniformity of the product, and only recently have satisfactory devices been constructed for the efficient elimination of the moisture in such cases. Again, the further development along this line in its effect on the character of the blast in Bessemer converter operations is such that possibly its utilization in this process will put the latter on an efficient basis where it can compete again with the open hearth process. In air compression as well, the presence of moisture in the air is well understood, and its limiting effect on efficiency can be greatly diminished by proper study and prevention of this phenomenon. These developments represent a comparatively few of the processes in which the presence of moisture in the air affects the efficiency of the operation, but they are essentially the more important classes and give a fair idea of the importance of this factor in engineering progress.

The fact that water vapour exists in the air has been known for a long time, and very good and satisfactory data have been at hand in regard to its amount under all conditions, and the methods of its measurement or determination are quite simple and readily available under all conditions. The problem itself from a physical or engineering viewpoint is essentially a single development of the broader one involved in the mixture of two or more vapours or gases or gases and vapours and the laws governing their relative proportions under variable conditions of temperature and pressures are fairly well understood, although this development is one in physical science which is undergoing rapid progress to-day. The basic conditions or laws which govern all these relations are primarily the fundamental laws of gases and vapours. Thus Boyle's

law holds for a gas independent of the presence of some other gas or vapour. In an equal sense Charles' law, showing relation between pressure, volume and temperature of the gas, is equally true, independent of the presence or intimate mixture of some other gas or vapour in the one under measurement. Dalton's law is the particular one that applies in these conditions, and, stated briefly, consists in the fact that all gases or vapours exist in conjunction with each other according to exactly the same laws that would hold if the others were not present. Thus, water vapour occupies space filled with air in precisely the manner that water vapour would tend to occupy space or vacuum if the air were not present. The ordinary atmospheric pressure of 14.7 pounds to the square inch is, therefore, according to this law, a combination pressure, due to the pressure of the atmosphere alone and the pressure of the water vapour present. The water vapour exists in quantities in this air dependent upon the temperature alone, and varies with it, and also with conditions which affect its degree of saturation. Thus, according to Dalton's law, if a cubic foot of dry air is taken, it will exert a definite pressure of, say, 14 pounds to the square inch. If a drop or two of water is injected into this, under normal conditions, the pressure will immediately rise from ½ to 1 pound to the square inch, and the pressure of the mixture will then be, approximately, 15 pounds, as recorded on an absolute pressure gauge. If a drop or two of alcohol is then injected into the mixture, the vapour of this liquid will tend to occupy the space in precisely the manner the water vapour has done and just as though the others were not present. Under these conditions the pressure will rise again from ¼ to ¾ of a pound, or a variable amount dependent upon the nature of the vapour and the temperature. As far as known, pressure can be increased indefinitely by this process by simply increasing the number of volatile liquids which are injected into a given space, and such pressure could undoubtedly be used for the production of work. However, the extent to which Dalton's law is true under such extreme conditions is problematical, and this development represents another phase in physical science which is undergoing investigation at the present time. However, the simple problem of the mixture of water vapour with the atmosphere is, as has been said, fairly well understood and represents to-day the chief development in which the practical aspect has been forced to the front in view of its great effect under operating conditions.

Now, a word in regard to the method of measuring the amount of moisture present in the atmosphere under various conditions, and some information in regard to its amount and effect in various engineering processes. The water vapour in the atmosphere can be readily removed by any chemical dryer. Thus, if a cubic foot of air or a given quantity is enclosed in a vessel containing lime or sulphuric acid, and the vessel shaken up, if desired, for more complete effect, all the moisture will be removed from the air and the pressure of the latter will fall. This latter phenomenon can be readily seen by opening a stopcock under such conditions, whereupon air will rush into the vessel after such procedure in order to balance the pressure. If the chemical agent, lime, calcium chloride, sulphuric acid or any well known dehydrators are weighed before and after this treatment, the moisture content for this quantity of air is absolutely determined, and a device or mechanism for the performance of this experiment readily and accurately is known as a chemical hygrometer. In actual practice in the physical laboratory this often consists of a tube filled with the drying agent, and suspended from one arm of a delicate balance and through which air is

pumped, the air being metered for this purpose and the amount of moisture is at once determinable. However, the process presents capabilities of much modification and means are at hand for ready determination, under any conditions, of the actual amount of moisture, in pounds or grams, present at any time in any amount of air.

While this value is of very great importance under many operative conditions, its relation to another value, namely, the saturation content, is often of much greater significance. This brings us, in reality, to the fundamental differences between what is known as a saturated and unsaturated vapour. In general, a saturated vapour can be defined as a vapour in which the quantity of material held is at its maximum. Any increase in the material present in the space either due to actual introduction, or to an increase in density caused by pressure, will cause a deposition or condensation of a portion of this vapour into its liquid form. It is analogous to what is known as the dew-point in atmospheric conditions, and at this latter temperature the ordinary air contains saturated water vapour. The space above a liquid invariably becomes filled with the vapour of that liquid to its maximum extent, and hence is a saturated vapour. Any variation, as stated, or a diminution in temperature results in a condensation or diminution in the weight of the vapour present. Thus one condition for the presence of a saturated vapour is the presence of a liquid surface of the same material immediately contiguous both in regard to time and place. Thus the water vapour in the air is saturated or not saturated, dependent solely upon the presence of large quantities of water in the vicinity or the close time relationship of the air in its contact with this surface. When a gas or vapour is heated, it tends to expand and occupy a larger space. Hence a saturated vapour gradually becomes in an unsaturated condition with rise in temperature, and is capable of absorbing, on contact with its own liquid, an amount of the material in the form of vapour sufficient to render it saturated. The amount of water vapour present under saturated conditions is readily determined from the ordinary steam tables, since these in almost all cases represent conditions approximating those favorable for complete saturation. The amount of saturated vapour which the air can, therefore, hold at any given temperature is readily determined by a reference to the steam tables for this temperature, and this steam pressure in practice is represented by a certain definite fraction of what is known as ordinary atmospheric pressure. The relation of the amount of water vapour present in the air to the amount that the air could contain if the steam or vapour existed in a saturated state, is known as the hygrometric state or percentage of humidity and is of very great importance in engineering practice, especially in cooling tower operation and allied phenomena, since it represents the capabilities of the air in regard to its absorptive power for moisture present in surrounding bodies, and hence its cooling effect in cooling towers and its drying capabilities as a dehydrator. While the ratio of the amount of moisture present in any definite amount of air to the amount that it should contain at this temperature, as determined according to the steam tables, is known, as has been said, as the hygrometric state, yet this ratio is numerically equal to a number of other different ratios relating to the same phenomenon. Hence this state is often defined in a number of other ways which often enable it to be measured much more readily and satisfactorily than can be done by this procedure. Thus the pressure of a saturated vapour is a function of the temperature only, and is independent of the volume. Hence the amount of material present in a saturated va-

pour is proportional to its pressure. In the same way the pressure of an unsaturated vapour is proportional to the amount of material present, if the temperature and volume are kept constant. Hence the unsaturated pressure of a vapour is proportional to the amount present, and the hygrometric state reduces to a ratio of the pressures of the unsaturated and saturated vapours which are present or can exist under given identical conditions. This ratio of the pressures is equal numerically to the ratio of the weights and is known as the relative humidity or the hygrometric state, and with some instruments, designed for this purpose, is much simpler in its determination than is possible by a direct determination than is possible by a direct determination of the weights, even though one has been determined and is obtainable from the steam tables. Again, since the pressure of a saturated vapour is directly proportional to its temperature, and somewhat analogous conditions hold for unsaturated vapours, the ratio can be reduced to temperature variations and we have the hygrometric state or relative humidity of a given air content as a simple function of its temperature and the temperature of its dew point, namely, that temperature to which the air must be lowered in order that water shall be condensed or dew produced readily.

Nearly all hygrometers, other than the chemical one, utilize this last relationship for the determination of the moisture content and relative humidity. They consist essentially of two thermometer bulbs, one of which records the temperature under given conditions, and the other is surrounded by some cooling agent whose temperature it records at the time when dew is produced or moisture has become perceptible in this form in the immediate vicinity. Thus the wet-and-dry bulb hygrometer consists simply of two thermometers, one of which has its bulb surrounded with an ordinary cotton wick which has its end immersed in a tube of water. The capillary action keeps the wick moist, and the evaporation into the air produces the cooling effect which is at once perceptible in the reading of the thermometer. The scale used with this device is a purely arbitrary one, determined through calibration with a chemical hygrometer or dew-point measuring device, but gives fairly satisfactory and accurate results of the relative humidity. This latter quantity is a quantity which, reduced to percentage and multiplied by the value obtained from the steam tables, gives the amount of water content in a unit quantity or volume of air.

The actual dew-point hygrometer, so-called, consists of two thermometers, one for the registering of the atmospheric temperature and the other for the determination of the dew point. This latter thermometer is surrounded by another bulb, into which ether or some other volatile liquid can be poured and rapidly evaporated by passing air through it by means of blowing or by the action of an ordinary water aspirator. This bulb containing the ether is partially covered by a polished metallic surface, and when the cooling effect produced by the evaporation of the ether has continued a sufficient time, this surface will become covered with moisture, due to the condensation of the water vapour present in the air, and the temperature at which this occurs is recorded by the thermometer, which gives the temperature of the boiling or evaporating ether. This device is much more satisfactory than any of the arbitrary calibrated ones, of which the thread hygrometer is undoubtedly the worst. This consists simply of a silk, or specially prepared fibre, fastened to a device for amplification and measuring of its motion, so that small variations in its length can be readily measured. When this fibre becomes wet, it becomes shorter, and its length is roughly proportional to the amount of moisture present in the fibre.

which, in turn, is dependent on the amount present in the air. Hence this device can be roughly calibrated to act as a hygrometer by complete reference of its values as arbitrarily determined to a standard hygrometer. However, it is not a sensitive instrument and responds slowly to variations in this state, and hence possesses little value as an accurate measuring device.

This represents a review of the ordinary hygrometric instruments and methods available for this development. The amount of water vapour present under ordinary conditions is comparatively small, being, approximately, 5.85 grains per cubic foot as an average for a five days' test at the installation of the refrigerating plant for the removal of moisture from the blast in iron furnace operation at the Isabella furnace of the Carnegie Steel Company at Ætna, Pa. This represents approximately normal values. It varies, however, from one grain to as high as eight or more, and even considerably larger values represent fairly average conditions in the tropics. The eastern sea coast of the United States represents a much greater hygrometric average than is present in the Middle West, and this latter bears almost an equal ratio to Rocky Mountain conditions. In the installation mentioned, each grain of moisture content per cubic foot meant a water removal of 40 gallons per hour, so that the effect, in the aggregate, is by no means negligible. In addition to its effect in blast-furnace operation and internal-combustion motors and air compression, its significance in cooling towers and their operation is equally pronounced. A cooling tower on a dry day may readily cool steam condenser water of 160 degrees to 200 degrees F., to values as low as 70 degrees or 80 degrees F., whereas on a moist, warm day the fall in temperature may not exceed one-half to one-third of this. The temperature of the air is, in reality, a matter of minor significance, and a number of tests are under consideration by cooling-tower manufacturers, undertaken with a view to the actual introduction of heated air into the cooling tower for the purpose of increasing the cooling effect on account of the increased possibilities in absorption of water vapour under these conditions. The fact that mechanical refrigeration has been proved to be a most efficient device in the removal of the water present in the air, and the further fact that this mechanical refrigeration can often be produced by the utilization of exhaust steam, a commodity or by-product often wasted under many conditions of installation, represents a condition which permits of its development for this purpose with a comparatively high degree of efficiency. The situation is such that practically no engineer can afford to-day to be without this knowledge in regard to hygrometric conditions, and to have some conception of the effects of the presence of the moisture in the air upon any special process in which he is interested.

AN IMPRESSION OF THE BLERIOT MONOPLANE

By A. B. Rigby

THE first impression made on the majority of those who availed themselves of the opportunity given for a close inspection of the Bleriot monoplane is that the machine looks extremely small. And herein lies its attractiveness.

On investigation, one is still further impressed with the fact that great progress has been made in the science of flight when a machine with a wing area of only 15¾ square feet, propelled by an engine developing only 20 horse-power, can be self-supporting and, at the same time, carry a driver, who need not necessarily be below the weight of an average man.

On this machine M. Bleriot crossed the English Channel on Sunday, July 26, 1909, completing a distance of 31 miles in 43 minutes. During this flight be attained a speed of more than 40 miles an hour.

Th following details give the approximate weights and measurements:

Total weight	496 pounds
Total length	26 ft. 3 ins.
Span of wings	25 ft. 7 ins.
Span of elevating planes	11 ft. 7 ins.
Superficial area of wings	150¾ sq. ft.
Length of blades	3 ft. 8½ ins.
Engine	20-HP. "Anzani" (two blades, three cylinders, air cooled).

The details of this machine are worthy of careful notice. Starting at the propeller, one naturally wants to know why it is made of wood, this seems so fragile. Probably weight considerations decided the inventor in the choice of material.

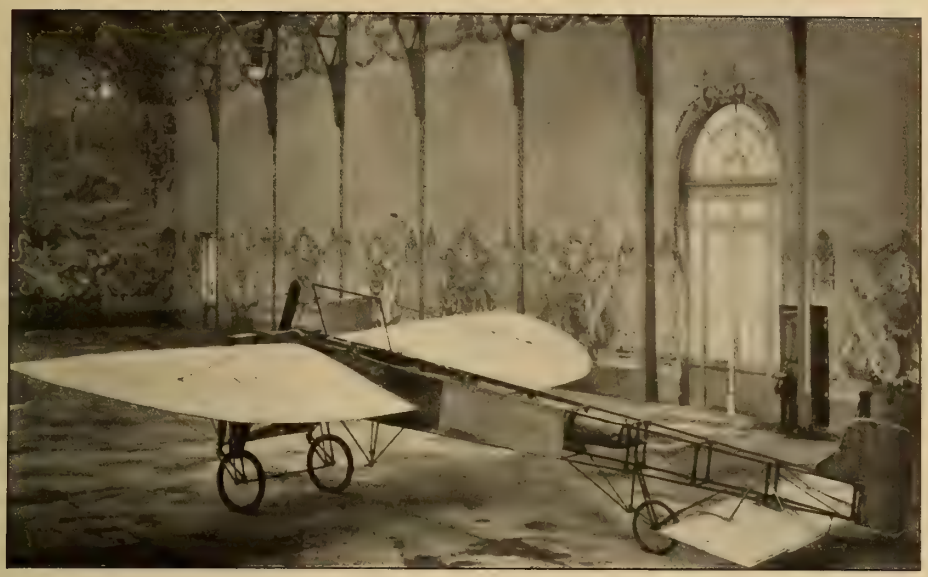
Then in the engine we see a three-cylinder, air-cooled engine nicely made, but very much on the lines of the ordinary, every-day engine one sees on motor bicycles; no elaborate care seems to have been spent on reducing the weight (as far as outside appearances go), and the engine seems to be substantial and not particularly small for the horse-power it is said to develop.

There are one or two points which are open to criticism. First, the use of automatic inlet valves, which are certainly not as dependable as mechanically operated valves; secondly, the contact maker on the ignition system seemed to be exposed to the elements; and thirdly, the exhaust ports point directly towards the body of the machine and towards the driver, an arrangement which must be very unpleasant from the driver's point of view, and might be dangerous, as they apparently are very close to the fabric of the wings.

The arrangement of the induction pipes, carburetor, petrol tank, etc., calls for no special comment, as they are installed in the simplest possible way; the only criticism likely to be made is that they appear to be entirely unprotected.

The engine and its accessories, including the propeller, are supported at the front end of a rectangular framework, which forms the body of the machine and which tapers away to the rear, ending up in a rudder very much resembling a fish's tail.

Close to the rear end of the body frame is attached a pair of fixed fins, or planes, one on either side, standing out at right angles to the body frame in a horizontal plane. The ends of these fins, or planes, are movable, being pivoted in the centre, so that they can be deflected from the horizontal position by means of a crosspiece or tiller-head



THE BLÉRIOT MONOPLANE
Total weight, 496 lbs.; total length, 26 ft. 3 ins.; span of wings, 25 ft. 7 ins.

operated by two steel wires secured to the ends of the tiller-head. These planes are apparently used for elevating or depressing the machine during flight.

The fish-like tail is also pivoted and operated by a cross-arm, or tiller-head, and is apparently used only for turning the machine either to right or left during flight.

Now we come to the device for operating the elevating planes, or rudder, which is neatness and simplicity itself, as are most of the details of this wonderful machine.

The four steel wires (two attached to the tiller-head operating the elevating planes and two attached to the tiller-head operating the rudder) are brought forward along the body frame and pass through guide-pulleys attached to a board secured horizontally to the underneath members of the body frame just in front of the driver. These pulleys are spaced so that the wires come up through the board at points equivalent to the corners of a square, the square being arranged so that the wires controlling the elevating planes come up at points in a line with the direction of flight and the two wires controlling the tail at points at right angles to the direction of flight. The four wires are firmly secured to a disc, which is shaped like a dish placed upside down, and having the wires attached to the edge. This dished disc is provided on the underneath side with a universal joint secured to the centre of the disc, and also secured to the board through which the controlling wires pass; and from the centre of the upper side of the disc a handle protrudes with a right-angled crook at the top, like a walking stick. The driver sits in a seat directly behind this controlling mechanism, with the control handle coming up between his legs.

It will be at once seen how beautifully simple the control becomes—a movement of the control handle forward or backwards in the line of flight elevating or depressing the machine, whilst a movement to right or left across the line of flight turning the machine to left or right.

The disc operating the control

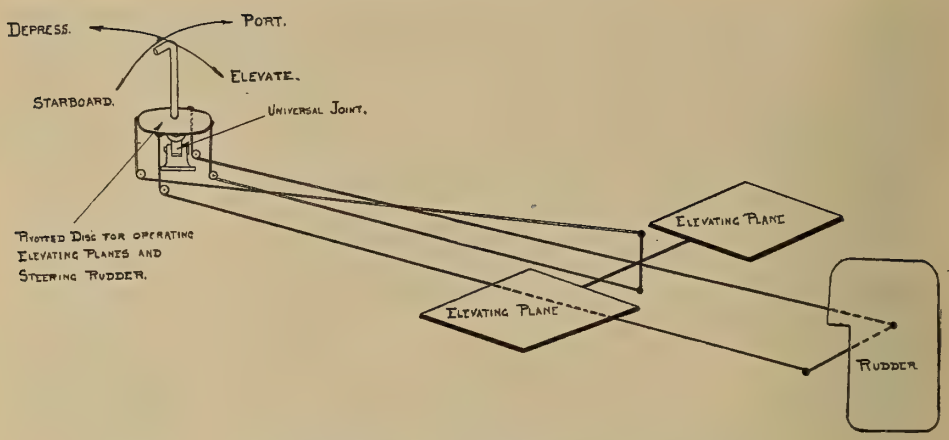


DIAGRAM OF UNIVERSAL CONTROL FOR BLÉRIOT MONOPLANE

wires being mounted on a universal joint allows a combined movement of the elevating planes and the steering rudder, and, no doubt, complicated evolutions could, with practice, be carried out with the greatest ease and with little effort on the part of the driver.

This single lever control is, undoubtedly, a very well thought-out piece of mechanism.

As to the body frame and lifting planes, or wings, the structure is composed principally of light ash scantling tied with steel wire and ribbon, very fragile, apparently, but extremely light. A noticeable point about the lifting planes, which are rigidly attached to the body frame, is their similarity in shape and construction to the wing of a bird, being thickened along the cutting edge, tapering away to a thin edge at the rear. The framework of the lifting planes or wings has fabric on either side, leaving air space in between—a valuable asset, probably, in the event of the machine coming down into water, as the wing would certainly materially add to its floating powers.

The machine is provided with two wire-spoked wheels at the forward end, and one at the rear for starting and alighting, provided with rubber shock absorbers, so arranged as to allow considerable movement of the wheels on alighting—a very necessary precaution with so frail a structure.

The general impression created by a careful inspection is that the machine, as built, has a great many good points about it, from an engineering point of view, yet the general construction can only be accepted as experimental; and the framework is so extremely fragile that one wonders how alighting at any time is possible without causing serious damage.

CONCRETE PIER CONSTRUCTION ON THE PACIFIC COAST

THE NEW REINFORCED-CONCRETE WHARF AT SANTA MONICA

By H. H. Dunn

IN view of the widely extending use of sand, lime and cement in construction, from the dwelling cast in moulds to the towering sky-scraper knit together with slight bars of steel, it is of especial interest to note the successful completion of the first concrete pier on the Pacific Coast of America.

Extending in a straight line 1,600 feet out into the Pacific Ocean, this latest example in wharf construction has just been completed at Santa Monica, where the longest wharf in the world—the Southern Pacific Railroad's pier at Port Los Angeles—is already located. So far—and the piles of the landward end of the new pier have been in position for several months—the sea has not made the slightest impression on the concrete posts. Teredos, those sea worms which make the life of the wharf builder a continuous nightmare, are powerless to penetrate the new piles; barnacles cling to them in small numbers, but can do no damage, while the strongest waves of the sea break aimlessly against the smooth concrete and without deleterious results to the wharf which they support.

All the girders, bents, stringers, struts and piles in this pier are of concrete. Twenty-one feet above mean tide level these concrete "timbers" carry the floor of the wharf, itself also made of cement and sand. The ocean bed at the foot of Ocean Avenue, of which the pier is a continuation, is of firm, white sand, sloping seaward at an inclination of 2 feet in every 100 feet of outward distance.

The promenade which takes up the floor of the new pier is 35 feet wide over all, and it is supported on trestle bents, spaced 20 feet, centre to centre. At the end of the pier there is a large platform (40 by 90 feet) handsomely decorated with cement work and brilliantly illuminated. At two intermediate points in the length of the wharf are other platforms, similar in size, decoration and lighting. Primarily the pier was planned to be a pleasure promenade, but it will also carry an 18-inch sewer pipe and serve as a landing place for small pleasure boats from other parts of Santa Monica and from near-by beach resorts of the south coast.

Reinforced-concrete girders, 35 feet long, huge gray monoliths, rest on the trestle bents. These latter are made up of three reinforced-concrete piles, spaced 13 feet 6 inches, centre to centre. These piles set at the usual angle against the shore currents and, with their concrete girders, give a peculiar air of solidity and stability to the novel structure.

Under the platform spaces there are trestle bents also, but these are made up of seven piles, similarly placed and capped with a reinforced-concrete girder, 90 feet long, overhanging at the ends like the lintel of some great stone doorway. In themselves these 90-foot beams of cement are unique, and they have attracted fully as much attention as have the huge cylindrical piles on which the concrete pier rests.

The trestle bents just described are still more strongly united by reinforced-concrete struts 9 by 18 inches in section, their reinforcement consisting of four 1-inch steel rods, 21 feet long. The girders forming the capping for the piles are 9 by 30 inches in section, reinforced by two

BATTERY OF PILES AFTER COMING OUT OF THE MOULDS

One end of a mould can be seen at the right lower corner of the photo. Some idea of the size of the piles can be gained by comparison with the man in the photo and with the two trolley cars standing in the background.

bars each, ½ by 2¼ inches, placed within 2 inches of the bottom of the girder; two bars, each ¼ by 2¼ inches, placed within 2 inches of the top of the girder, these bars connected by ¼ by 1-inch diagonal members and vertical members of the same size, all bolted together and solidified with three 8-inch bolts. Over each centre pile are two additional bars, ½ by 2¼ inches, 8 feet long, bolted to the top chord. In addition to this, there are, in each span, eight spacing-bolts with gas-pipe separators; and in the compression side of the overhang of the girder are two rods, ¾ of an inch in diameter, 4 feet long.

The platform spaces are similarly reinforced, allowing greater length to the rods and bolts, owing to the greater width of the platforms, as compared to the width of the promenade.

But the chief interest among residents of Santa Monica centered in the huge piles. Prior to starting actual work on the pier, great cylindrical moulds were built on the sloping bank of the sea near the end of Ocean Avenue. In these the piles were cast vertically and in such position that a traveling crane at the landward end of the first false-structure of the pier could pick them up with ease from the point where they had been rolled out of the moulds.

Measuring 75 feet in length, and varying from 14 to 22 inches in diameter, the weight of each pile averaged more than five tons.

Each pile has a great bulb point, with which it anchors itself in the sand, which is very firm and unshifting at this point in the sea wall. Also, within each pile is a 2-inch jet pipe, down which the water was sent

to sink the shaft into the bed of the ocean. When the piles were firmly set in their resting places all these jet pipes were filled with wet cement.

The reinforcement for the 14-inch pile consists of six ¾-inch steel rods, arranged symmetrically 2 inches from the outside of the pile and bound together every 3 feet of length with No. 12 wire. Where it was found necessary to splice the rods, they were lapped 2 feet and wrapped with No. 14 wire to a 2-inch pitch. The lower ends of the rods are splayed into the bulbs, the upper ends into brackets, and carried 28 inches above the head of the piles to mesh into the reinforcement of the girder and strut. In each bracket under the strut were placed two additional rods, 9 feet 6 inches long, and of the same size as the reinforcement rods.

The reinforcement of the 18-inch pile consists of eight ¾-inch rods; that of the 22-inch pile eight ⅞-inch rods; all other details of the 14-inch pile apply to these sizes.

After the piles were made each one was given a jacket of No. 12 steel, 9 feet long, enclosing the monolith from a point 3 feet below the line of mean low water to a point 6 feet above the same mark, thus insuring the covering also of the average high-water line. These jackets were then coated with an asphalt composition to prevent rust. It should be said here, however, that under the steel sheath each pile was painted with a preparation composed of one part neat cement to six parts of water.

The piles were sunk in the sand to depths varying from 16 to 20 feet, according to the condition in which the engineer found the character of the bottom. With the aid of the water jet running down the centre of each of the concrete piles, little difficulty was experienced in getting

STEEL CRANE LIFTING SOLID CONCRETE PILES FROM RACK TO PLACE THEM ON TRUCK TO BE WHEELED OUT TO PILE-DRIVER

RAISING PILE INTO POSITION FOR DRIVING

them down, their weight being so great that only a small amount of driving was found necessary.

The stringers on which the promenade "deck" is carried, are 4 inches by 16 inches, 22 feet long, and spaced 2 feet 6 inches, centre to centre. They are anchored to the girders with half-inch steel rods. On the outside the stringers are 4 by 16 inches, but only 20 feet long, with joints butted and fished with four ¾-inch machine bolts.

The floor pan, to hold the asphalt floor, is made of 2-inch plank, breaking all joints on the stringers. A 2 by 4-inch scantling, laid flat, was nailed to the outer edge of the planking for the asphalt covering to finish against. This covering is 4 inches thick at the centre, sloping to 2 inches at the sides. All around the wharf is a railing of 2-inch galvanized iron pipe, 42 inches high, with iron posts every 6 feet. Two rows of pipe are attached to these posts aside from the railing itself, and one of them carries fresh water, with hydrants and fire plugs at convenient distances. Thirty-four lighting poles, 18 feet high, and made from 3, 4 and 5-inch pipe, carry electric lamps for the illumination of the pier.

Two landing stages are provided at the seaward end of the pier; but these are made of wood, fastened to concrete fender piles, with concrete struts binding them together. These floats are 10 by 20 feet, and stairways lead from them up to the main floor of the pier. The fender piles mentioned are ten in number, 12 inches in diameter at the butt and driven 20 feet into the bed of the sea. They are placed in a sort of irregular semicircle around the outer end of the wharf.

The specifications embodied in the first papers looking to the construction of this wharf are of especial interest to concrete engineers and to contractors, inasmuch as their close application appears to have been a large factor in the success of the novel pier. They are as follows, quoted verbatim from the specification of Mr. Thomas H. James, city engineer of Santa Monica:

"All concrete shall be a wet mixture of one part cement and six parts

aggregate, the latter consisting generally of two parts of sand and four parts of broken stone.

"The cement shall be a recognized standard brand of artificial Portland cement in satisfactory use on this coast for a period of not less than two years; it shall show an ultimate tensile strength at the end of seven days of not less than 400 pounds per square inch.

"The fineness shall be such that not more than 10 per cent. by weight shall remain on a No. 100 sieve.

"It shall develop initial set in not less than thirty minutes, but must develop hard set in not less than one hour nor more than ten hours.

"Pats of neat cement shall, in water, in air and in an atmosphere of steam, remain constant in volume.

"All tests shall be made in accordance with the methods proposed by the committee on uniform tests of the American Society of Civil Engineers. A sufficient supply of cement shall be kept on hand to permit of tests lasting twelve days.

"The sand shall be clean, coarse and sharp.

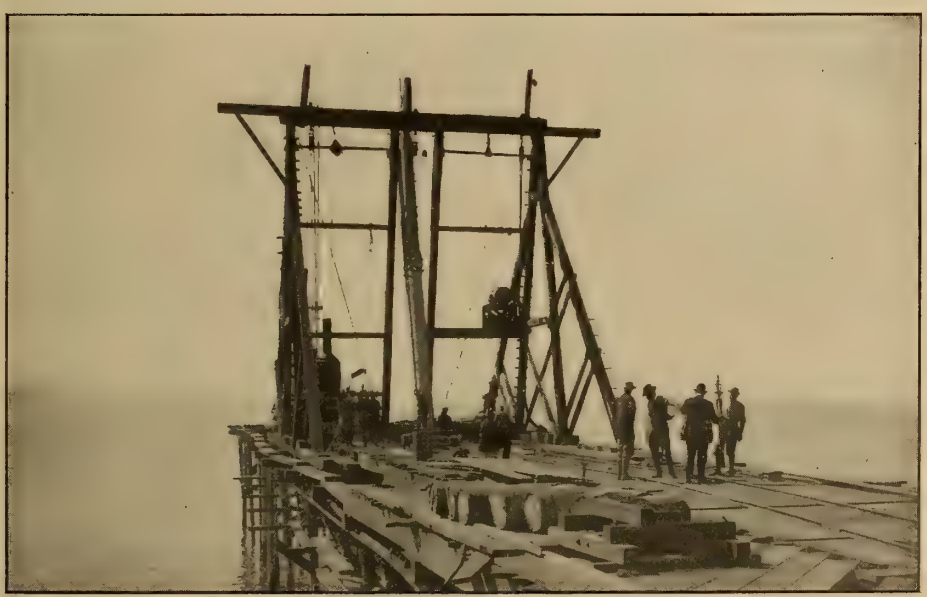
"Stone shall be a hard, durable rock, broken to a maximum size of 1 inch in any direction for use in pile construction. In all other work a maximum of 2 inches in any direction will be permitted.

"If mixed by hand, the cement and sand shall be placed in layers and mixed dry until of a uniform color; the mixture shall then be spread uniformly on the stone and turned three times, water being added to the first turning. * * * Concrete shall be placed in the forms immediately after mixing, and shall be so conveyed that there shall be no separation of ingredients.

"All steel shall be good, merchantable steel, having an ultimate tensile strength of 50,000 to 60,000 pounds per square inch.

"All forms shall remain in place three weeks unless otherwise permitted by the engineer, in which case the concrete shall be protected from the sun and all exposed surfaces wet twice daily for three weeks after the casting.

"The asphalt pavement shall consist of a binder course 2½ inches thick at the centre of the pier and ½ inch thick at the edges, and a



CONCRETE PILE READY TO BE SET FOR DRIVING

DRIVING THE FIRST PILE IN THE CONCRETE WHARF AT SANTA MONICA, CAL.

A COMPLETED SECTION OF THE CONCRETE PIER BEFORE THE WOODEN FALSE WORK WAS REMOVED

Note the concrete girders and stringers, presenting a peculiar appearance after so many years of wooden wharves.

wearing surface uniformly 1½ inches thick."

The binder course consists of broken stone and asphaltic cement; the wearing surface is made up as follows:

Asphaltic cement, 9 per cent. to 17 per cent. by weight; sand, 86 per cent to 65 per cent. by weight; finely powdered carbonite of lime, granite, quartz, or other suitable material, 5 per cent. to 18 per cent. by weight.

The contractor was not permitted to sublet any of the work without the express permission of the city engineer, and the result was that some of the finest cement work ever seen on the Pacific Coast was turned out. This, combined with the cheapness of the work and its apparent durability, though this last feature has yet to be fully proven, seems to show that Santa Monica has started a new era in ocean-pier construction.

CONCRETING STRUCTURAL FOUNDATIONS

By F. A. Lart, A.M.I.C.E.

SOME time ago, in connection with a discussion before the Institution of Civil Engineers on the construction of a concrete railway viaduct in the southwest of England, the writer put forward a suggestion that structural foundations should be solidified and made good, as regards the natural ground, by a process of concretion, *in situ* and in bulk, by the injection of liquid cement or lime mortar into the natural soil whenever its porosity would allow such treatment.

Such a process would obviously be impossible in the case of solid material like rock or clay, impervious in the mass, and probably of sufficient natural solidity to withstand the compression of weighty structures erected upon it.

The writer, in conceiving and publicly putting forward this idea, as recorded in the Proceedings of the Institution of Civil Engineers (Vol. CLX., 1904-5), was quite well aware of the very ordinary practice of injecting liquid cement or mortar grout into concrete and other built-up masonry structures where failure and want of cohesion rendered such a proceeding obviously necessary. But he was not then nor has he since become aware that his idea of concreting and solidifying natural foundations by the method he then suggested, to be described in this article, had or has ever been put forward by anyone else, or put into practice. If this had been the case he would undoubtedly have heard of it at the time his suggestion was made or subsequently, both as a check upon his own originality and as a record of what he feels assured would prove an entirely satisfactory solution of many difficult problems as regards providing new structures with cheap and efficient foundations or solidifying those which for any reason have, since the buildings were placed upon them, failed to firmly sustain the usually very heavy loads that almost all engineering or architectural foundations are caused to bear through overloading or through some natural or induced change in the native soil underlying the superadded artificial foundations on which such structures immediately rest.

The provision of adequate and immovable artificial foundations for engineering structures such as bridges and workshops, or for isolated units of machinery, such as heavy rolling-mills or electrical or steam-engine plants, is the first care of the engineer, and is at all times an anxious one. So also as regards the architect and the buildings which he designs and erects.

It is obvious that on the efficiency of the foundation depends entirely the rigidity, the safety and the efficiency of the structure or the machinery it carries.

We have had for the last three years or so—and have before us at the present moment, emphasized by appeals for public subscriptions to make good the heavy damage already sustained, and to mitigate and avoid the imminent danger that lies ahead—the case of the Winchester Cathedral, where the failure of these all-important foundations has already considerably damaged the greater part of the structure and has jeopardized the safety of the whole.

And whereas in this case, as in many others of a very similar nature and extent, this failure of the foundations appears to be quite sudden or to show itself quite suddenly, it is, in fact, merely the demonstration of a process of decay and failure

which has been taking place and developing secretly and unseen and often unexpected for a considerable and indefinite period. It is in no case possible to predict with any certainty or reasonable probability that the foundations of any structure, whether natural or artificial, are permanent and everlasting, notwithstanding any extreme care of construction and nicety of calculation in regard to the assumed or known rates they or the superincumbent structure may be called upon to bear.

In the case of bridges carrying railway or simple road traffic the sudden and unexpected and excessive development of speed and weight, both distributed and concentrated, is almost as inevitable, nowadays at least, as the much smaller and more reasonable and gradual increases in all of these that were intelligently anticipated and carefully estimated and allowed for when these structures were designed.

The strengthening of steel and masonry bridges on the various railway systems of England, for instance, became quite suddenly necessary in a brief period of time only a few years ago, when an entirely unlooked-for, and it may be said in many instances quite uncalled-for development of locomotives, as regards their size, weight and power, came as a surprise and something of an anxiety to those responsible for the upkeep of the permanent way and the bridge work carrying and connected with it.

A development of this kind, whether it comes suddenly or with due warning, involves very considerable expense, for it clearly means, except in a few cases where existing structures can be strengthened without removal and without replacement, the entire removal of bridges and other structures originally designed with an ample margin of safety and of adequate strength for the needs of the period of construction and the reasonable developments of the future, and their replacement by entirely new structures of necessarily considerably increased size and weight and cost, since they have been designed to accommodate, with safety and with an adequate margin of strength and durability, the new conditions of traffic that have arisen, and for which the older structures are obviously and dangerously insufficient.

How awkward and difficult the task of such replacement of bridges and kindred structures is only those who have had to carry out such work in the usual minimum possible time know or can properly appreciate.

And when, as may well and frequently happen, the foundations of the original structure require also to be renewed, the task becomes more than doubly difficult.

The provision of suitable foundations in the first instance for any structure is usually a very expensive process and the cost an appreciable percentage of the entire completed work, even in cases where Nature has generously provided what are known as "natural" foundations in the shape of solid rock or stable, and only minutely compressible clay or other material of an equally durable character. The depth and truth even of these require to be fully proved in every case before the careful engineer or architect will trust such "natural" foundations to carry, through the interposition of his own artificial foundations and "footings," carefully distributed so as to impose only a small and reasonable percentage of his total load on the unit area of the ultimate "natural" foundations themselves, the final burden which they are destined to carry in perpetuity.

Nothing can be taken for granted, even with rock which is apparently solid; still less when, as in the case of a clay or gravel apparently firm and solid enough, a peaty or waterlogged substratum may or is known to underlie the otherwise reliable surface material. It must not be supposed, however, that even these are incapable or untrustworthy of safely carrying heavy structures and of

forming adequate and permanently reliable foundations.

Massive structures, such as St. Paul's and Winchester and Peterborough Cathedrals and the abbeys of Selby and Crowland, for instance, have stood for centuries on water-logged gravel, sand and peaty foundations and subsoil, the "footings" or constructed foundations resting directly, perhaps, on wood piles driven deep into the natural foundations or subsoil, which hold them in an immovable grip and wedge—like embrace and foundations such as these would not have failed, as some have done, of themselves, either by decay of the piles or by compression and shrinkage of the subsoil. In every case where failure has developed through causes such as these, and sinkage and disintegration of the superincumbent structure have shown themselves as a result, as in the buildings above mentioned, both the cause and its effects are directly and unmistakably attributable to the diminution or release of that hydrostatic pressure which alone enables such natural foundations to preserve rigidity and incompressible volume.

It is simply drainage of the subsoil through natural causes, or more usually through the agency of man seeking to reclaim adjacent swamp lands, which, by robbing the whole volume of the subsoil, including that over and upon which a cathedral or other structure is built, causes the piles to shrink and the water-swollen soil to shrink also and loosen its grip of them so that the "footings" or artificial foundations of the structure sink and break under the load they carry. Even rock, especially that of a porous and naturally saturate character, is liable to shrinkage and compression and disintegration when drained of the moisture which it contains, and which, being itself incompressible, is in every way as effective for the support of considerable weights and in its resistance to crushing stresses as the solid material of the rock itself.

The preparation of swampy ground and water-saturated subsoils to provide adequate, reliable and permanent foundations for carrying heavy engineering and kindred structures is naturally a problem of some anxiety to the engineer and the architect and of great interest and importance. In the case of a river bed, for instance, upon which a permanent masonry bridge, or the masonry or concrete foundations for a steel bridge, require to rest, it may be, and very frequently is, impossible to find bed-rock foundations below the gravel or sandy soil of the river bed, even though one goes down seventy or a hundred or more feet through the river bed to find it. Nor is a solid rock foundation necessarily indispensable in such cases.

Some of the heaviest structures known, as, for instance, Rennie's Waterloo Bridge over the Thames, which is constructed entirely of granite and of very solid proportions, and London Bridge also, built of the same materials and of much the same solidity, both of which bridges are as heavy as any structure of the kind can well be, are founded on wood platforms lying upon and fastened to vertical piles driven into the natural river bed of gravel and clay, and in no case resting in or upon anything more solid: there is not even the London chalk beneath them. Here, then, amongst many others of a precisely similar character, we have an instance, or instances, of the reliability of gravel, sand and clay as natural foundations for carrying very heavy structures without difficulty and without any reasonable liability of failure for all time, simply through the constant and practicably equable hydrostatic pressure of the water they are saturated and covered with.

But the civil engineer and the architect of to-day is both a more fearful and a more thorough man than the builders of a century ago, and of those preceding centuries which were responsible for engineer-

ing and architectural works and structures that were then and are now both relatively and often actually in excess of, as regards weight and stupendousness and boldness and ingenuity of conception and execution, any that the modern engineer or architect of the past fifty or seventy years has ventured or been able to produce, with all the vastly developed demands for great engineering and architectural structures, and the appliances for carrying them into effect which this period has produced and made available.

The modern engineer or architect is, perhaps, rightly desirous of erring, if at all, on the safe side, and insists on his foundations, both natural and artificial, being unimpeachable and constructed of so permanent a character and materials as to be entirely independent of any extraneous changes or influences which may affect them directly or indirectly. The older engineers and architects of by-gone days, while they were extremely and properly cautious and exercised very great care and judgment, were content, also, and, indeed, frequently constrained to take risks often considerable; and it must be admitted that both their caution and their boldness have been amply justified by time and the passage of events. And these precautions are taken nowadays for every kind of engineering or architectural structure, great or small, and without any particular reference to its ultimate purpose or use; that is to say, the foundations of a merely static structure, such as a water-tower or a church or a monument, are formed with as much care and thoroughness as those for a structure such as a bridge which carries a constantly moving and variable load, or for some heavy machinery, such as a rolling-mill or a heavy electrical generating plant, where there is constant vibration and oscillation, and a constant and direct, and frequently alternating, strain on the machinery, as well as on its foundations.

The writer thinks, however, as a practical engineer, that it is legitimate and often desirable to differentiate between structures which are merely static in themselves and as regards their functions and structures which, on the other hand, are either not in repose themselves or which, at any rate, carry and are subject to the disturbing influences of moving weights and vibratory and similar strains and stresses. It is quite possible that a bridge which carries the normal traffic of the streets, both pedestrian and wheeled, but always moving, may be perfectly reliable as to its foundations and structure in all perpetuity as regards such traffic, the effect of which upon both structure and foundations is necessarily imperceptible and "nil." But it does not necessarily, and in all probability would not, follow that the structure itself or the foundations on which it rests is or are capable of carrying with equal efficiency, as regards absence of ill effects or with permanent reliability or even temporary safety, the much heavier and more destructive traffic of heavy motor vehicles, trams, or railway rolling stock. And herein lies a distinct danger to the Thames bridges above referred to, in which the writer fully believes some signs of failure will inevitably show themselves sooner or later, owing to the greatly increased and more frequent rolling weights which they have suddenly and unexpectedly been called upon to carry, and for which they were certainly not constructed. Their one hope lies in the unimpeachable excellence of their construction and their materials and their foundations. Nothing but qualities and properties such as these and the absence, in those better and more honest days, of any trade-union nonsense and chicanery in the workmen employed on such works could enable a structure such as Richmond Bridge—one of the most beautiful works of its kind and of its own and all periods of bridge-building—to stand the excessive strain of motor-buses, trac-

tion-engines and heavy horse vehicles which abuse its carrying powers to-day, and for carrying which it was not intended or constructed. So, also, with another stone structure—Kingston Bridge—which carries heavy trams in addition to the loads mentioned above. But it is extremely probable that both of these fine and efficient structures will soon show signs of wear and tear and undue strain, not, probably, as regards their foundations, but their superstructures, in which the various blocks of stone may become loosened and separated through the gradual disintegration under constant vibratory stresses and the imperceptible movements under concentrated and rolling loads of the stones, of the mortar or cement which binds the individual blocks of stone and the whole structure together.

We may now proceed to examine more closely the method suggested by the writer for providing secure and cheap foundations in unfavourable subsoils, such as gravel, sand, peat, artificially deposited rubble or ash, or other loose and porous materials, whether normally saturated and water-logged or naturally dry, and which in themselves are quite untrustworthy and unsuitable for carrying any structure which the engineer or architect may have to put upon them, static or otherwise.

The usual method, and the one universally adopted wherever practicable for preparing foundations, is for materials such as these to be excavated and entirely removed, to a bulk and extent sufficient for the purpose, and replaced by solid masses of artificial concrete, which is either deposited in bulk so as to form a solid and continuous monolith or built up of blocks cemented together when in place, or to construct a continuous and practically monolithic mass of ordinary brickwork or rubble masonry. Each and all of these methods are extremely costly; and, as a matter of fact, it may frequently happen that the mere cost of preparing foundations such as these, or sinking piers to form gigantic foundation piles, is nearly or entirely equal to or even in excess of the cost of the entire superstructure. In any case, it is expected, as a matter of course, that the cost of foundations will be a very appreciable proportion of the cost of the entire work. The writer's method avoids all these defects and provides foundations which are absolutely permanent and reliable in regard to all natural subsoils of the kinds referred to and of a similar nature. It consists simply in saturating such materials as they stand, *in situ*, and without any excavation or preparation of any kind (except the possible removal of any earthy or brittle or dirty surface soil or material, though these would not necessarily be harmful) and mere rubbish, or perhaps the preparatory drainage by some simple and inexpensive means of superfluous moisture in the ground to be treated other than any levelling or similar preparation of the surface which might be deemed desirable or necessary for the quicker application of the superimposed artificial foundations or footings or of the structure itself with liquid cement or lime mortar grouting under suitable pressure and allowing this to set and solidify into a solid mass of concrete. By this means any extent and any depth and cubic volume of natural subsoil of a porous character, whether wholly or partially saturated and water-logged or not, can be rapidly, completely and efficiently converted into a solid mass of cement or lime-mortar concrete having a perfect natural bond with the surrounding unconcreted subsoil and unmovable relative thereto, being buried in and tied to it, and of itself except by some powerful disruptive force such as those blasting materials which are used to break up masses of concrete and solid rock. The process of grouting is simplicity itself, and either follows the ordinary methods of compressed air or other artificial and applied force or can be effected

by using a "head" of liquid cement or lime-mortar grout sufficient to provide adequate pressure to enable the material to force its way into and to thoroughly permeate the entire mass of the subsoil to the depth required. Whatever pressure is used requires to be discounted to the extent of the normal atmospheric pressure and a reasonable percentage on account of pipe friction to which the flow of liquid grout is naturally subject, since the incoming grout has to displace any air or moisture there may be in the subsoil material, forcing it out against the pressure of the atmosphere, and the traverse of the liquid grout in the feed pipes is necessarily somewhat retarded, according to the length and diameter of the pipes and some other circumstances through friction. Any extent, depth and mass of subsoil can be thus saturated and concreted by sinking a sufficient number of supply pipes to a sufficient vertical depth and at sufficient and perfectly regular intervals into the subsoil to be treated.

As the writer originally formulated the idea in the connection above referred to, he prefers that where a large area and depth and cubic mass of material have to be dealt with to form a solid, homogeneous concreted mass and solid foundation, there should be a number of rigid steel or cast-iron pipes, say one per 4 square feet of surface, or, if the depth is not too great, per 6 square feet, sunk or driven vertically down into the subsoil, and preferably to the maximum depth of the required foundations. The upper ends of such pipes are preferably left projecting conveniently above the surface of the ground for facility of handling and removal (if desired) and attachment of the supply pipe from the grouting machine or reservoir; the supply pipe is preferably of the metallic flexible type, capable of standing the necessary internal pressure at which the grout is injected. The pipes are preferably two, or not more than three inches diameter inside, and for the lower half or two-thirds of their depth in the ground are perforated with ¼-inch or ⅜-inch holes all round and sufficiently close together, in regular pitch, to provide an adequate and equable outflow of the grout into the surrounding subsoil. The bottom ends of the pipes may be closed, and have one or two holes in it also, for the same purpose. If the ends are left open, too much grout is liable to escape downwards. In sinking these perforated pipes they are preferably plugged with a wood core or with another unperforated pipe, and kept so until the grouting is to be forced into them, so that they are clean and not obstructed; in any case, they should be cleared before the grout is injected. When sunk in saturated ground they will serve as sumps and drain pipes, from which, if it is considered desirable, water may be extracted from the soil, or will automatically drain off by accumulation and overflow as local springs, previous to grouting. It is not necessary, but it is desirable, that as many pipes and as much subsoil as possible shall be grouted up simultaneously. It is usually only practicable, however, to deal with a limited number of pipes and mass of subsoil at a time, to avoid excess and complication of the grouting plant. In any case, pipes fed in groups or singly should be adjacent to each other, so as to form a connected or progressive mass in the subsoil which they feed. The complete grout saturation of the subsoil shows itself by the grout making its appearance at the surface, and the degree of porosity of the subsoil will determine the number of pipes which are necessary per unit of surface area and of depth and cubic mass for completely saturating the required total cubic volume of subsoil. In loose, dry, porous subsoil, or in only slightly saturated material, fewer supply pipes and a more copious delivery of cement or lime-mortar grouting will be possible than in stiff, less porous and more saturated ground, where

the resistance is greater and it will not travel so easily. It is necessary to have an excess rather than a deficiency of grouting applied at any point, so as to insure the most rapid and complete saturation of the subsoil possible. As soon as the grout makes its appearance at the surface of the ground round about the supply pipes the saturation of the subsoil may be considered as complete and satisfactory, and will usually be found so on examination afterwards, if it is thought desirable to prove it. The pipes themselves should then be at once withdrawn from the ground—unless it is preferred to leave them in for any future developments—before the grouting has had time to set (otherwise they will only be removable later on with difficulty, and possibly not at all, being firmly and solidly concreted in the ground), and the flexible metallic feed pipes can be at once attached to the nearest adjacent group of pipes required to be used, the work proceeding throughout on a regular and organized plan, preferably as little interrupted as possible, so as to insure continuity in the saturation of the required bulk of subsoil and homogeneity in the resulting concrete mass.

The several processes are preferably continued without intermission until the entire mass is completely grouted up, and without allowing sufficient delay between operations for any grouted area or mass to become solid before the subsoil adjacent to it is similarly saturated. This is not, however, by any means absolutely necessary for efficiently carrying out the work, since the grout travels at will from the supply pipes in the ground amongst the porous material, forming an irregular and variable contact with the adjacent ungrouted mass of the subsoil, and providing, therefore, an irregular and arbitrary and perfect bond with the grout which is thereafter introduced. Thus, even if any grouted mass is allowed to solidify, by design or through the quick-setting properties of the grout employed, before the adjacent masses and the entire required mass are also grout-saturated, no harm can result, and the bonding of the already solidified mass with the liquid cement or lime-mortar grout which follows later, and the resulting concrete, at any distance of time, will be practically and for all practical purposes as complete and the whole mass as solid and homogeneous as if the process had been simultaneous throughout. The strength and substance and fluidity of the cement or lime-mortar grout employed require to be determined according to the circumstances of each particular case.

The greater the porosity of the subsoil and the degree of its water saturation the thicker, consistent with facility of flow, the liquid grout ought to be, both to prevent its traveling too far and too quickly and beyond the required range, and also to counteract the thinning effect of the water in the subsoil. The bulk of this water, at least in very porous and saturated material, will actually be displaced by the injected grout and will appear at the surface of the ground if there is no other or more ready outlet for it, since the water in the adjacent un-grouted mass of the subsoil will not and cannot give it room. The supply pipes may, in fact, be used to drive out some or all of the water in the subsoil before grouting, if desired, by air pressure, through connecting the pipes sunk in the soil with a compressed air plant such as might be used for injecting the grout.

All subsoils and porous materials, including peat, have a certain definite capacity of saturation, and this cannot be exceeded, so that the injection under considerable pressure of another liquid, such as cement grout, is bound to displace more or less of the water of saturation, according to the pressure employed, forcing it to escape by the easiest path that presents itself, just as if it were air. And in this process it may be found

that such water is escaping from some or all of the open supply pipes adjacent to those through which at any moment grout is being injected into the subsoil and so displacing the water in it.

For dense subsoils and fissured rock which it may be desired to solidify, such as porous lava rock, more fluid grouting is required to insure its thorough penetration.

By feeding from well below the surface of the ground, as described, there is better assurance of getting out whatever moisture or air the subsoil may contain, as well as of thorough saturation in all directions, to a final overflow on the surface of the incoming grout. The subsoil will necessarily only accommodate a certain amount of grout, determined and fixed by the degree of porosity or interstitial space, and when fully saturated therewith the overflow must show itself or proceed somewhere, so that its appearance on the surface of the ground round the supply pipe or pipes that may be in course of being fed at any moment is a certain indication that the whole mass of the subsoil under treatment at the moment and served by those pipes has been completely penetrated, saturated and concreted. In cases where the penetration of the mass is expected to be slow, the grout should not only be sufficiently fluid to travel, but also sufficiently slow setting to insure it remaining fluid until it is all finally in place and the whole mass thoroughly saturated with it. Indeed, it is hardly conceivable that under any circumstances—except, perhaps, in works and subsoils lying permanently under water, such as in the beds of rivers or on ground subject to tidal covering — quick-setting cement or mortar grouting would be required or desirable.

There is no limit to the quality or character of the grout used in the writer's process: it may be pure Portland cement, or marine cement, or blue lias lime-mortar, or ordinary mortar of, preferably, any adequately hard-setting and binding quality. Whatever is used must necessarily be of a kind best adapted to form the best possible concrete with the natural subsoil materials.

The injection pressure used will depend both on the depth and extent of the injection and the degree of porosity or the density of the subsoil to be treated, and, incidentally, on the consistency of the liquid grout.

Every case will require to be dealt with on its own merits, and it would be impossible to generalize further than to say that this system happily requires only the cheapest cement material to be used—unless, of course, better qualities are required—since it affords an unusual and hitherto unknown and unthought-of method, and one of extreme simplicity and cheapness, of forming solid, homogeneous concrete foundations of any extent and without any limits by the mere binding together of natural masses of loose materials, closely packed in the majority of cases and in all cases quite properly arranged and assorted by nature to form perfect or sufficient concrete by the mere artificial addition of a cement to bind them together. Upon foundations so prepared, unmovable, incompressible, and associated and incorporated with the earth's crust itself, the engineer and the architect can lay their supplementary or artificial foundations and footings and rear upon them structures of any size and weight, fit for any purpose and durable for all time, with entire confidence in the reliability and unfailing endurance of the all-important subsoil on which they ultimately or primarily rest.

The writer has found that ordinary clay is practically impervious to any grouting under any pressure up to 150 pounds per square inch, a pressure which would very rarely be required, if at all, in making use of this process. Peat, dry or saturated partly or wholly, can be perfectly satisfactorily concreted with either Portland cement or ordinary lime-mortar or hydraulic lime-mortar or cement,

forming a mass which is not easy to cut, and is capable of sustaining considerable loads per unit area. The writer knows of no chemical or other objection to the concreting of peat with Portland cement, there being no inter-relative chemicals in either that he knows of which would, in the first place, prevent or ultimately destroy the concretion thus formed. In any case, even if this were so, and the natural acids in the peat prevented the hydration of the cement, lime-mortar would act perfectly well and form an absolutely permanent and durable concrete. Cinders and ashes and refuse of a similar character can be quite easily concreted up by this process, either with Portland cement or lime-mortar grouting, the latter being preferable as forming, perhaps—though the writer does not think this has been quite satisfactorily proved—more durable concrete with these materials. Concrete so prepared will stand considerable pressure—very much in excess of what the loose, untreated materials would support—and by this means the abutments or foundations of bridges formed in or upon cinder embankments of railways, as is very common, could be made much more reliable than they are now, where the material is so loose and treacherous and susceptible to damp and floods, and liable to scour and waste away by the formation of mud and dust.

The writer does not suggest that with such unpromising and unusual materials as these concrete can be made, by his process or by any other method, equal in quality to that usually made and specified for engineering or architectural purposes. Nor does he guarantee that his method of concreting masses of natural ground *in situ* by the forced injection of liquid cement or mortar grout will necessarily or in every or any particular case result in concrete of the same quality and strength as if such materials were assorted and mixed by hand and formed into concrete in the usual way. What he does claim for his process and insists upon, and is prepared to prove, is that it will produce in any material which is amenable to the treatment described, properly carried out, and with reasonably good cement or mortar grout, masses of solid concreted foundations of strength, durability and reliability much in excess of what such material or subsoil naturally possesses, and entirely suitable for the general purposes of the engineer or the architect as an efficient substitute for the infinitely more expensive foundations that are usually specially constructed and considered necessary for carrying heavy structures or plant or machinery, static or otherwise, which special foundations always involve the complete removal of subsoils of this nature and other special preparation of the site, such as boring, to prove the lower strata, and do not necessarily even include the use, partial or entire, of the material thus excavated for forming the massive artificial concrete foundations put down in their place. It is surely unnecessary to insist, to practical and reasonable men, on the obvious economy of thus substituting a simple and direct process of preparing foundations for those laborious and costly and not necessarily more effective methods that are usually employed and considered indispensable. The writer hopes that contractors and engineers and architects who may be interested in the ideas the writer has put forward in this article may be induced to give them a fair trial.

Some time ago, when the failure of the foundations of Winchester Cathedral and the resulting damage to the fabric itself came prominently before the public, the writer ventured to lay before the responsible authorities proposals for dealing with these defects by the method described. His suggestions received courteous and careful consideration and were ultimately referred to the consulting architect and engineer who had been called in to advise, when he was informed that another method had

been decided upon, which has since been in process of execution. That was three years ago, and the work is not yet anything like completed, while the cost of it has, as is usual in these cases, very considerably outrun the original and subsequent estimates.

The writer cannot help thinking and publicly stating that, had these ideas been adopted and put into execution at once under his superintendence and according to the proposals which he laid before the Cathedral authorities, the foundations and the fabric of the Cathedral would have long since been made good and absolutely assured for all time in a very brief period of time—two or three months would probably have sufficed—and at less than one-quarter of what has already been expended on the still incomplete work as now being carried out. In saying this the writer does not wish to disparage the thoroughness of the methods which the consulting engineer and architect have advised and carried out; he thinks there is not much doubt as to their efficiency and permanency; nor, unfortunately, can there be any doubt as to their extreme laboriousness and costliness, or the developments, actual and probable, of the primary and of subsequent damage to the fabric arising from the piecemeal and delayed treatment of the necessary work, the progressive nature of which necessarily throws upon the untreated foundations and the fabric whose weight they carry an intensity of load and strain which they are ill able to bear.

By the above method the entire foundations could, if necessary, have been solidified by permanent concretion of any extent of the subsoil on which the structure rests, simultaneously and without any necessity for costly underpinning (though this might have appeared desirable in parts for the time being, and pending necessary repairs to or reconstruction of the actually shattered fabric), and without the slightest disturbance of any kind to the footings, of the walls, the piles, or the superstructure.

CHANNEL STEAMERS

By Arthur Barter, A.M.I.N.A.

Although the steamships designed especially for service on the English Channel and the Irish Sea naturally possess peculiar features determined largely by the special conditions of the service, yet they represent a class of steamship well adapted for other localities, and hence the following paper by Mr. Barter will be found of interest and value to marine architects in various parts of the world.—THE EDITOR.

THE rapid development in speed and accommodation on the various routes from England to Ireland and the Continent during recent years has brought the cross-Channel steamer into prominence, second only to that of the fast ocean liner, of which she is the smaller prototype. In designing this type of ship the marine architect is confronted with many features similar to those which characterize the larger "greyhound"; but the main distinction is in the shorter journey traversed and the ability, therefore, to provide for greater power within reason at the expense of fuel consumption, the economy of which is of greater importance in the long-distance ship.

That it is possible to maintain a high speed with these small vessels is attributable to the following reasons:

(1) Length of run is comparatively short, thereby obviating the necessity for frequent cleaning of fires and consequently the maintenance of a full pressure of steam.

(2) Vessels are chiefly engaged in the carriage of mails, passengers and cattle traffic, which is conducive to light draft and displacement.

The total displacement may be analyzed into the following components:

Displacement.
Light weight. Dead weight.
Hull. Machinery.
Steel work. Wood and fittings. Engines and Boilers.

and the method of approximating the weights of the various parts is by using coefficients which have been deduced from a number of similar ships. These are obtained by dividing the net weights of steel and wood with fittings by a cubic number derived from the product of the length, breadth and depth divided by 100, while the weight of machinery is obtained either in terms of indicated horse-power per ton of machinery or tons of machinery per I. H. P.

For cross-Channel steamers of from 20 to 23 knots, the machinery coefficients may be taken as—

Type of Machinery	I. H. P. per Ton Machinery	Tons Engines per I. H. P.	Tons Boilers per I. H. P.
Turbines	12	.022	.055
Reciprocating engines.	9	.041	.070

or the hull weights of a 20-knot vessel absorbs about 55 per cent. of the working displacement, reciprocating machinery about 35 per cent., leaving 10 per cent. for deadweight carrying capacity.

With the adoption of turbine machinery, the margin available for deadweight is appreciably increased, as may be judged from the coefficients shown above; or the lighter weight per I. H. P. may be utilized by providing increased power and speed. In the Midland Railway Company's steamer *Antrim* the total weight of reciprocating machinery was 767 tons, as compared with the 575 tons in the case of her turbine-propelled sister-ship *Londonderry*.

A similar comparison can be made with the machinery of the new turbine steamers *Duke of Cumberland* and *Duke of Argyll,* recently built by Messrs. Denny & Bros., of Dumbarton, for the Lancashire & Yorkshire and London & North-Western Railway Companies' joint service between Fleetwood and Belfast. These vessels displace about 2,600 tons on a draught of 12 feet 9 inches, and are built for a speed of 20½ knots. The turbine machinery in these vessels weighs about 116 tons less than that of their sister-ship *Duke of Albany,* with reciprocating engines.

DINING SALOON ON THE CROSS-CHANNEL STEAMER "ANTRIM"

As pioneers of the cross-Channel traffic, the City of Dublin Steam Packet Company have maintained a reputation for comfort and regularity of time on their Holyhead-Kingston service which would be difficult to improve. In 1860 this company put four paddle-wheel steamers on the service, called the *Ulster, Munster, Leinster* and *Connaught,* after the four Irish provinces. These vessels were 328 feet long, 35 feet beam, and nearly 13 feet mean draught, with a displacement of 2,035 tons; and for a period of fourteen years the mean time was 3 hours 56 minutes over the distance of 64 nautical miles.

The progress of development led to these paddle-wheelers being replaced in 1897 by four new twin-screw vessels, reducing the passage to 3 hours. These vessels were somewhat larger than their predecessors, having dimensions increased to 360 feet by 41 feet 6 inches by 29 feet 3 inches, displacing 2,185 tons on a draught of 13 feet. The boilers have a steam pressure of 175 pounds, and are worked under forced draught on the closed stokehole principle. The four-cylinder, triple-expansion en-

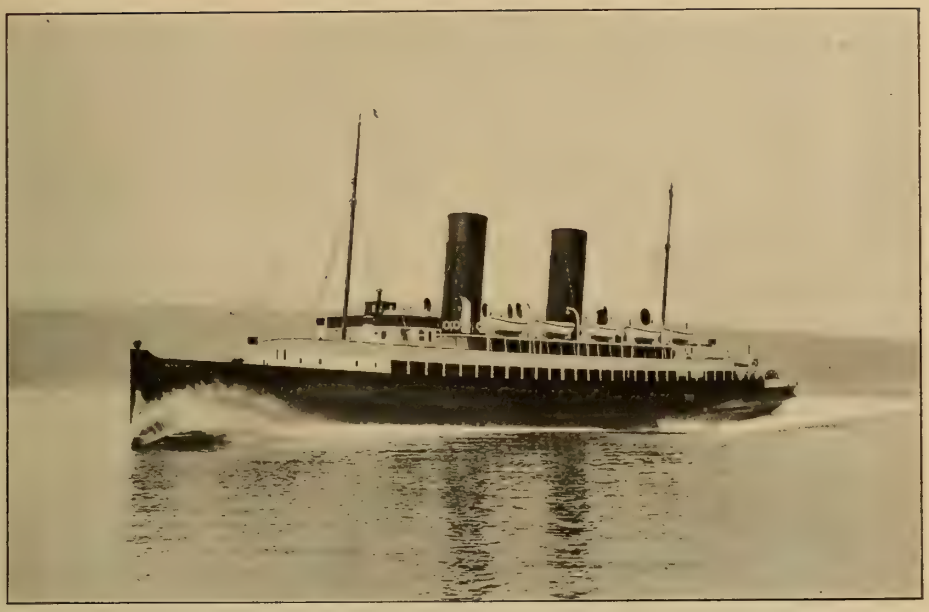
STEAMSHIP "LEINSTER"

gines make 175 revolutions per minute, and have a piston speed of 960 feet per minute. This is a great advance on the machinery of their earlier namesakes, with their 25 pounds boiler pressure, oscillating engines making 26 revolutions per minute, and a piston speed of 340 feet per minute; but although the engines of the newer vessels develop nearly twice the horse-power of the earlier ships, yet the weight is not 10 per cent. heavier.

Similar progress has been made on other lines, and in the following tables some particulars of the principal steamers on the various routes are given.

The length of passage varies considerably, from one hour on the

TURBINE STEAMSHIP "LONDONDERRY"



TURBINE STEAMER "BEN-MY-CHREE"

Calais-Dover service to six hours on the Fleetwood and Heysham routes to Ireland; and according to length of passage, and also as the service is a daylight or night one, so the internal arrangements of the vessels must be designed to meet the requirements of passengers as regards sleeping accommodations and the provision of meals.

On the four principal routes to Ireland via Fishguard, Holyhead, Fleetwood and Heysham a considerable number of well-appointed staterooms are fitted, while the galley and saloon arrangements are necessarily of an extensive character for supplying a number of people with hot meals and light refreshments. Sufficient coal-bunker capacity must also be provided to enable the vessel to cover the double journey with a margin left for port use and emergencies.

The same applies to vessels on the

TURBINE STEAMER "DUKE OF ARGYLL" ENTERING FLEETWOOD HARBOUR STERN FIRST

Harwich-Hook of Holland and the Hull-to-Zeebrugge routes to the Continent. On the former service a splendid fleet is run by the Great Eastern Railway Company, the latest additions to which are the two turbine steamers *Copenhagen* and *Munich,* built by John Brown & Co., of Clydebank. Here the night passage lasts about 5½ hours, sufficiently long to warrant passengers "turning in" for the night.

The service between Hull and Zeebrugge was established only about three years ago, when the Lancashire & Yorkshire Railway Company placed their fine 18½-knot steamer *Duke of Clarence* on this route. This passage is about twice as long as the Hook of Holland line, but the railway journey to the principal towns of Belgium and Germany is considerably shortened.

With vessels running between Dover, Folkestone, Newhaven and the French ports, and between Liverpool and the Isle of Man, the passages are somewhat short, and are run throughout the daytime.

The accommodation of these vessels consists chiefly of deck space well sheltered from the weather, and an ample saloon fitted with sofa seats.

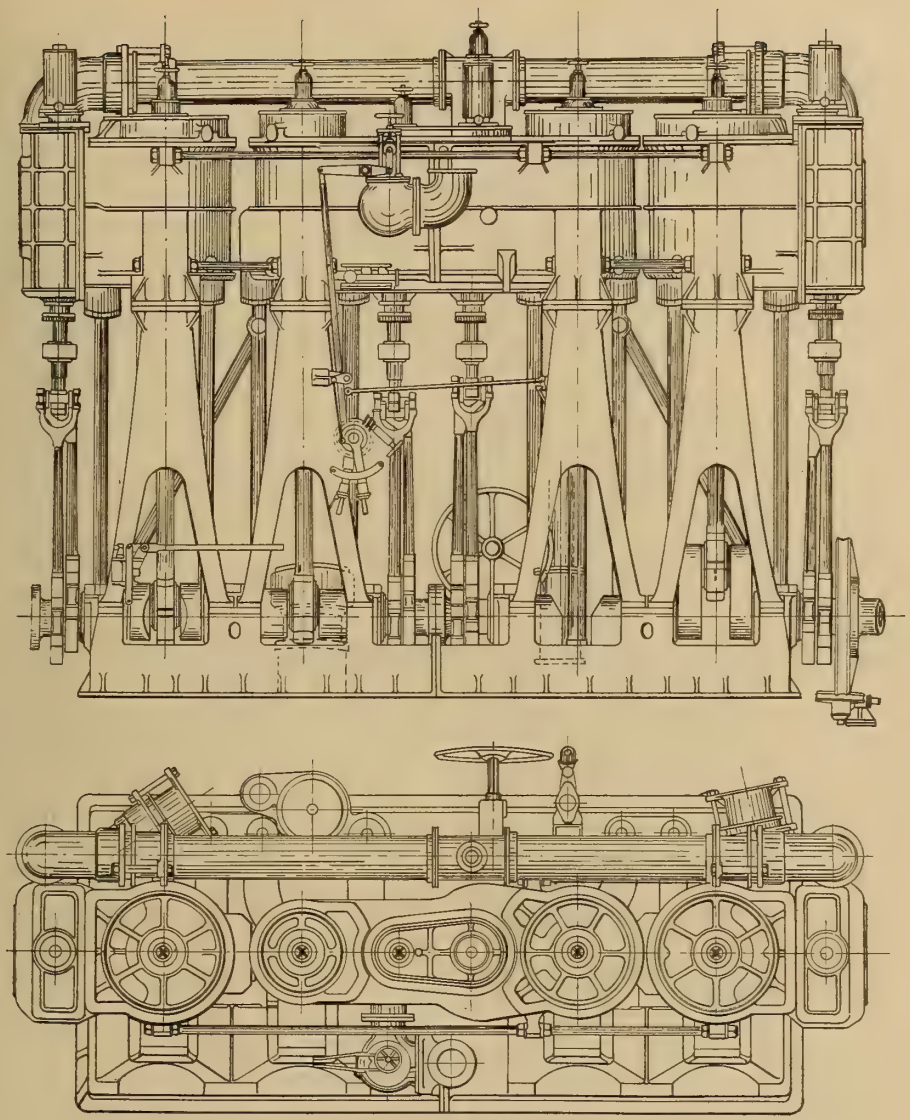
The machinery of modern cross-Channel steamers prior to the introduction of the turbine system of propulsion consisted principally of the four-cylinder, triple-expansion engines fitted in duplicate, with boilers working under forced draught.

In this type of engine the arrangement of the cylinders, with each of the low-pressure cylinders on either side of the high-pressure and intermediate-pressure, lends itself to the perfect balancing of the cranks and a reduction of that vibration which manifests itself in vessels fitted with the three-cylinder engine.

CORNER OF THE ENGINE-ROOM, TURBINE STEAMER "MUNICH"

With the turbine installation, the vibration over the engine room is even less marked than in the case of reciprocating engines balanced on the Yarrow-Schlick-Tweedy principle, but in many cases is accentuated at the stern—a result of the high rate of revolutions of the turbine propeller and the extreme fineness of lines of the after body associated with a light draught.

Practically nothing is gained in the floor space of the engine room by the adoption of turbines, and the saving of deck space derived from

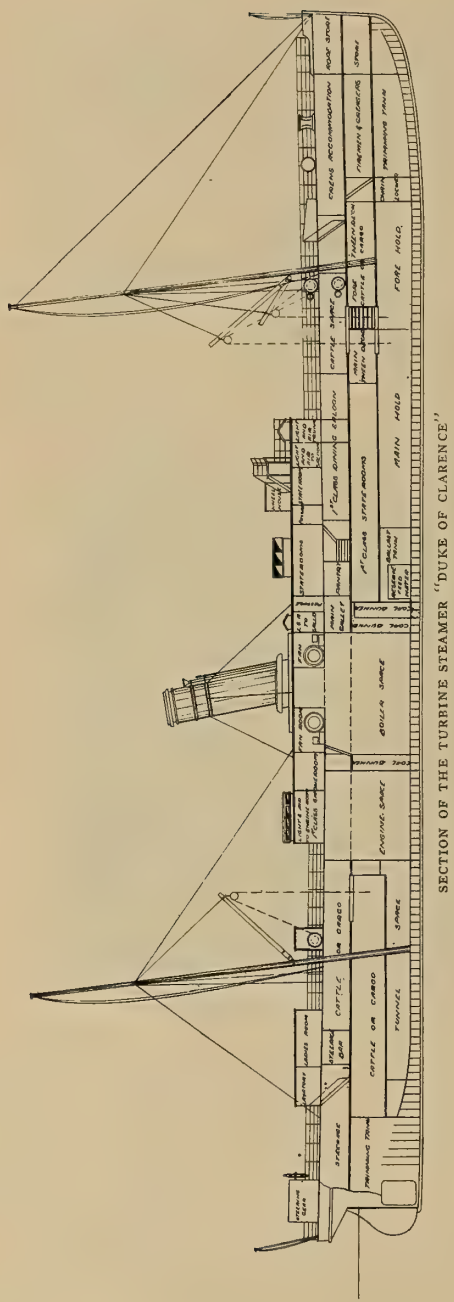


TYPICAL HIGH-SPEED, FOUR-CYLINDER, TRIPLE-EXPANSION ENGINE FOR CHANNEL STEAMER

smaller engine casings is of such a nature as to be frequently rendered useless for extra accommodation.

The task of making a reliable comparison in the coal consumption between sister-ships fitted with the two kinds of machinery is one of no small difficulty, owing to the fact that, whereas the shaft horse-power is readily ascertained in turbine-engined vessels, no suitable instrument has yet been devised that is capable of recording the variable torque in the shaft of the reciprocating engine. And as the shaft horse-power is the true measure of the power used in driving the ship, so upon this basis alone can the economy of fuel be measured. It is generally conceded, however, by shipowners with experience of this type of machinery that the turbine is, if anything, the more economical engine.

One of the disadvantages under



SECTION OF THE TURBINE STEAMER "DUKE OF CLARENCE"

which these turbine-driven vessels labour is with regard to their manœuvring powers, especially when compared with those propelled with ordinary twin screws. Many of the harbours frequented by Channel steamers are of a tortuous and tidal character, demanding very careful navigation when approaching the piers or landing stages. With twin reciprocating engines, full power can be transmitted equally to each shaft if the vessel is required to turn within a small circle, whereas with triple screws of the turbine vessel only one-third of the total power is available on one side from the low-pressure turbine for driving ahead, and about one-sixth on the other side from the astern turbine, according to whether the vessel is turning to port or starboard. When steering on the helm, however, the centre propeller acts directly on the inclined surface of the rudder, rendering the turning effort more effective. This handicap is, to some extent, remedied by the assistance of a bow rudder.

One of the most remarkable of this class of vessel, as representing the fastest Channel steamer afloat, is the Isle of Man Steam Packet Company's *Ben-my-Chree* (Woman of my Heart), particulars of which are culled from the Proceedings of the Institution of Naval Architects of this year.

This vessel has dimensions of 375 feet by 46 feet by 18 feet 6 inches, with a displacement of 3,353 tons on 13 feet 5 inches mean draught. The turbine machinery is of the Parsons type, with the usual arrangement of three shafts, the centre one actuated by the high-pressure turbine and each low-pressure driving the wing shafts. Steam is supplied by four double-ended boilers, each 16 feet 9 inches in diameter and 20 feet 7½ inches long, with eight furnaces, 3 feet 6 inches in diameter, worked on the closed stokehole principle, having a total grate area of 754 square feet and a total heating surface of 27,446 square feet. The working pressure of the boilers is 170 pounds per square inch.

The conditions on trial were specified to be 24 knots on a six-hour run, with boilers showing not more than 1¼ inches air pressure, the

PARTICULARS OF MODERN CROSS CHANNEL STEAMERS

Name of Steamer.	Owning Company.	Service.	Date.	Length B. P.	Beam.	Mean Draft.	Displacement in Tons.	Description.	Machinery Cylinders.	Stroke.	Speed on Trial Knots	Indicated H. P.	Tonnage Gross.	Tonnage Net.	Distance Between Terminal Ports in Nautical Miles.
"Duke of Clarence"	L. & Y. Ry. Co....	Hull & Zeebrugge...	1892	311′ 6″	36′ 0″	12′ 4″	1976	twin screw 3 cyl. trip.	22″ 34″ 51″	33″	18	3900	1437	648	205
"Chelmsford".....	G. E. Ry. Co.....	Harwich & Hook of Holland.....	1893	300′ 0″	34′ 6″	15′ 0″	2500	twin screw 3 cyl. trip.	26″ 39½″ 61″	36″	18.2	4800	1635	596	105
"Magic".....	Belfast Steamship Co	Liverpool & Belfast.	1893	310′ 0″	38′ 0″	13′ 0″	2370	twin screw 3 cyl. trip.	19″ 31″ 52″	36″	19	4200	1640	487	140
"Colleen Bawn"....	L. & Y. Ry. Co....	Liverpool & Drogheda.....	1903	260′ 0″	35′ 6″	12′ 5″	1890	twin screw 3 cyl. trip.	21″ 33″ 52″	30″	17.8	3812	1204	240	140
"Munster".....	City of Dublin S. P. Co.....	Holyhead & Kingston.....	1897	360′ 0″	41′ 6″	13′ 0″	2185	twin screw 4 cyl. trip.	29″ 45″ 2@ 48″	33″	24.15	9143	2633	733	60
"Anglia".....	L. & N. W. Ry. Co.	Holyhead & Dublin.	1900	330′ 0″	39′ 0″	11′ 5½″	2340	twin screw 4 cyl. trip.	26″ 40″ 2@ 43″	33″	21.20	7137	1862	313	60
"Brighton".....	L. B. & S. C. Ry. Co.	Newhaven & Dieppe	1903	273′ 6″	34′ 0″	10′ 0″	1350	3 steam turb.	...	...	21	5968	1129	301	64
"Antoin".....	Midland Ry. Co....	Heysham & Belfast..	1904	330′ 0″	42′ 0″	11′ 6″	2200	twin screw 4 cyl. trip.	23″ 36″ 2@ 42″	30″	21.86	7000	2100	589	123
"St. David".....	Great Western Ry..	Fishguard & Rosslare.....	1905	350′ 0″	41′ 0″	13′ 10″	2645	3 steam turb.	...	...	23	7200	2529	771	54
"Invicta".....	S.E. & Chatham Ry.	Dover & Calais.....	1905	311′ 0″	40′ 0″	9′ 7½″	1750	3 steam turb.	...	...	22.5	9000	1671	333	22
"Princess Elisabeth"	Belgian Government	Dover-Ostend.....	1905	344′ 0″	40′ 0″	9′ 6″	1973	3 steam turb.	...	...	24	12000	1747	787	68
"Princess Ena"....	L. & S. W. Ry. Co..	S'ampton & Channel Islands.....	1905	250′ 0″	33′ 0″	14′ 1″	1825	twin screw 3 cyl. trip.	16″ 26″ 41″	24″	16	2438	1198	502	...
"Viper".....	J. & G. Burns Ltd..	Ardrossan & Belfast	1906	315′ 0″	39′ 6″	13′ 6″	2835	3 steam turb.	...	...	21.64	6500	1713	192	...
"Viking".....	Isle of Man Steam Packet Co.....	Fleetwood & Douglas	1905	350′ 0″	42′ 0″	11′ 0″	2400	3 steam turb.	...	...	23.53	9500	1951	247	54
"Copenhagen".....	G. E. Ry. Co.....	Harwich & Hook of Holland.....	1907	330′ 0″	43′ 0″	14′ 6″	2975	3 steam turb.	...	...	21	8500	2570	780	150
"Duke of Albany"..	L. & Y. & L. & L. D. Ry. Cos.....	Fleetwood & Belfast	1907	330′ 0″	41′ 0″	13′ 0½″	2621	twin screw 4 cyl. trip.	25½″ 39½″ 2@ 43″	33″	20.53	8158	2259	709	120

ship to be capable of carrying about 2,500 passengers. The mean speed of 24½ knots was easily attained on trial, while for a portion of the run her speed was 25½ knots. On service, the results have been equally satisfactory, while the coal consumption amounts to 71 tons per day of two trips, equal to about 1.87 pounds per I. H. P. per hour, this including the coal used for raising steam for cooking purposes during the passage.

The owners of this fine vessel have reason to congratulate themselves on the success of their latest enterprise, and Messrs. Vickers' Sons & Maxim add another name to the already long list of famous vessels turned out from the Barrow yard.

One of the greatest difficulties which the naval architect has to overcome is to keep the net register tonnage to a minimum. The annual cost for dock charges is one of the heaviest items of expenditure with this type of ship, consequent upon their daily leaving and entering port. In order that this item may not be unduly heavy, large openings with loose covers are left in the deck, doorways are left off, alleyways and bulkheads are not continued above the height of the main deck in order to avoid the closing of those spaces, which otherwise would be included in the registered tonnage.

The tonnage per passenger will also vary, as staterooms are furnished with one or more berths. The size of a single-berth stateroom is, roughly, about 6 feet 6 inches by 4 feet 6 inches by 7 feet 6 inches high, or nearly 2¼ tons measurement. (Cubic capacity of space ÷ 100 = tons measurement.)

On the other hand, a four-berth room would only require to be slightly larger, about 6 feet 6 inches by 6 feet 6 inches by 7 feet 6 inches, or 3½ tons measurement. But whereas the tonnage per passenger in the single-berth room is 2¼ tons, it only amounts to ⅞ ton per passenger in the larger room.

Many passengers by these vessels would, no doubt, prefer the privacy of a single-berth stateroom; but this, together with high speed, is a luxury the heavy cost of which the layman can scarcely appreciate.

Items such as wages, fuel, oil, harbour-dues, insurance, general upkeep, etc., allow for little return on the capital invested for running these well-appointed Channel "fliers"; but enterprise is the dogged characteristic of the British shipowner, ever on the lookout for improvements both in design and equipment, so that the shipbuilder will never be wanting opportunities for exercising that ingenuity and foresight which have been the foundation of the chief industry of the British Islands.

THE LOSS OF HEAT FROM UNCOVERED STEAM PIPES

By William Ledyard Cathcart

THE action during the cooling of steam in the steam pipe is complex. Heat, as a form of kinetic energy, is transmitted by internal conduction through the mass of the steam, by external conduction from the steam to the metal of the pipe, by internal conduction through the latter, and finally by radiation to adjacent objects and by external conduction to the air, being diffused through the mass of the latter by convection currents.

If the steam be superheated, this action is complicated further by the state of motion of the steam which affects the external conductivity from the latter to the pipe, this conductivity growing as the steam velocity increases—an effect which is due to the fact that superheated steam approaches the state of a gas. This condition does not prevail with saturated steam. It may be readily shown mathematically, by calculation of the internal and external conductivities of the metal of a bare pipe conveying saturated steam, that increase in steam velocity, within the usual range in practice, will raise the amount of heat lost only by a quantity which lies within the limit of error of the ordinary test. This relative reluctance to deliver heat may be owing to the sluggish internal conductivity of saturated steam, but a more rational explanation seems to be that it cannot lose heat without partial condensation. Hence, a column of such steam has, in the pipe, always a thin casing of condensate; and, further, the interior surface of the pipe is also covered with a film of water whose thickness will depend on the viscosity of water at that temperature and on the velocity of the steam. These two films act as insulating coverings, since the internal conductivity of water is about one hundred and fifteen times less than that of iron, and the heat escaping from the mass of the steam must pass through this layer of water before it can reach the metal. With highly superheated steam this condition does not exist, since the pipe is at a temperature higher than the saturation temperature of the steam.

COEFFICIENTS OF CONDUCTIVITY

For clearness in subsequent discussion, it may be well to express the action of cooling steam in mathematical form. Thus, let Q be the quantity of heat lost during the time T through a pipe whose external area is A and thickness x; and let t_1 be the temperature of the steam, t_2 that of the heat-receiving surface of the pipe, t_3 that of its heat-delivering surface, and t_4 that of the air. Treating the pipe as a flat plate,

$$\begin{aligned} Q &= k_1 (t_1 - t_2) AT \\ &= k/x (t_2 - t_3) AT \\ &= k_2 (t_3 - t_4) AT, \end{aligned}$$

in which k is the coefficient of internal conductivity of the metal and k_1 and k_2 are the coefficients of external conductivity from steam to metal and from metal to air, respectively. These coefficients represent strictly only the mean conductivities for the temperatures given in their respective equations. It should be observed further that the temperatures t_2 and t_3 are those of the surface-layers of the metal and not of the films of fluid—steam or air — immediately in contact with those surfaces.

The reciprocal of the coefficient of conductivity is the thermal re-

sistance, r, r_1, and r_2, respectively, for the coefficients as above. By combination and elimination,

$$Q = \frac{1}{r_1 + x\,r + r_2}(t_1 - t_4)AT$$

The fraction in this expression represents the reciprocal of the sum of all the resistances met by the heat in transmission from one fluid to the other. It is, therefore, the general expression for the coefficient of heat-transmission between the two fluids—steam and air in this case—which coefficient is:

$$K_3 = \frac{1}{r_1 + x\,r + r_2} = \frac{1}{\frac{1}{K_1} + \frac{x}{K} + \frac{1}{K_2}}.$$

If the steam be superheated, its temperature will not be the same throughout as with saturated steam, since there will be a greater or less fall of temperature from the centre to the circumference of the mass. The temperature of the latter, and not that of the steam originally, will then correspond with t_1, as above.

SOME PREVENTIVE ERRORS

An error met occasionally in the treatment of this subject is that two bodies having the same form, size and character of surface, but of different composition internally, will, at the same temperature of the two surfaces, emit equal quantities of heat. This assumption disregards the part played by internal conduction, by means of which heat reaches the cooling surfaces. Since this action is inter-molecular, proceeding presumably either by the direct contact of, or radiation between, the molecules, its rate varies necessarily in different substances with a corresponding effect on the quantity of heat emitted. For example, four iron pipes of the same length and diameter filled, respectively, with steam, hot water, oil and air, and having the same temperature at their outer surfaces, will each emit different amounts of heat under the same external conditions and during the same period of time. Preston says: "The so-called 'coefficients of emission' (external conductivity) which have been as yet determined are only rough measurements involving what might be termed the emissivity proper of the substance, as well as the internal conductivity of the material, and other quantities depending on the nature of the enclosure."

A somewhat similar error is that of judging the conductivity, and hence the value, of a pipe-covering by its external temperature, especially when felt by the hand. This method is misleading for several reasons. First, external measurements of surface-temperatures have long been abandoned by physicists as untrustworthy, owing to the impossibility of eliminating errors due to the action of the film of air, steam, etc., which adheres to the surface. Again, as has been shown above, the surface-temperature is not the final factor, since internal conduction must be considered; for example, to take an extreme case, a very porous covering would feel cool, while, through the action of internal convection currents, it was leaking heat as a sieve would water. Finally, the sense of touch is deceptive in the measurement of temperature; if the hand has just previously been in contact with a heated body, a hot covering might feel relatively cool, and *vice versa*.

THE STEAM PIPE AS A COOLING BODY: DULONG AND PETIT'S EXPERIMENTS: PÉCLET'S EXPERIMENTS AND HIS FORMULÆ.

The steam pipe, although maintained at a practically constant temperature when in regular service, is essentially a "cooling body," as defined in physics, and its heat-losses are, therefore, governed by the laws of cooling. These laws, in their entirety, have not as yet been established. While both theory and the results of experiment indicate that the heat dissipated by radiation may

be ascertained, in close approximation, by the application of Stefan's law, but little is known, with absolute accuracy, as to the magnitude, under all conditions, of the further loss caused by conduction to the air and by the convection currents formed therein.

For the determination of the total losses of heat from steam pipes, the formulæ of Dulong and Petit, as modified subsequently by Péclet, have much value, since they cover approximately the required range of temperature and apply with reasonable accuracy throughout that range. The investigations of these physicists, however, while elaborate in character, were conducted within restricted limits of temperature and with special apparatus of small size, so constructed that all conditions during each experiment could be regulated with certainty. It should be observed, further, that the cooling bodies employed by Péclet were metallic vessels filled with hot water, the coefficient of emissivity of which differs somewhat from that of steam. On the other hand, Dr. Russner found that results obtained by the use of Péclet's radiation factor K compared favourably with those from Stefan's law; Stefan himself showed that there was a reasonable agreement of his law with Dulong and Petit's formula, on which that of Péclet is based; and Pasquay, the pioneer in the determination of the heat-losses of steam pipes, regards Péclet's formulæ as satisfactory bases for computing the minimum loss in any given case.

Dulong and Petit's experiments consisted wholly in observations on the cooling of large glass thermometers inserted in a closed chamber, the latter being kept at a uniform temperature and being either filled with air or gases at various pressures or exhausted of air so that heat was lost by the thermometer only through radiation in a vacuum. The bulb of each thermometer was large, and formed the cooling body; it only was heated, and only it and as small a part of the stem as was necessary were inserted in the cooling chamber; the projecting part of the stem was so protected as to keep it as nearly as possible at the temperature of the surrounding air.

From a most elaborate series of experiments of this type, long regarded as classic, these investigators deduced the well-known laws of cooling which bear their names. The formulæ for the rates of cooling by radiation and by conduction which were embodied in these laws could not, however, be employed in general practice, since they contained coefficients whose value was required for each body whose loss of heat in cooling was to be observed.

Péclet, therefore, instituted a subsequent series of experiments whose primary object was to put these formulæ in such shape as to make them available in all technical calculations. With this end in view, he limited his tests to those on bodies cooling in air at atmospheric pressure and in a chamber with dull walls, that average conditions might be approached. In place of thermometers as cooling bodies, he used small spheres, cylinders and various rectangular vessels, all of thin brass. Each of these vessels was successively tested, when filled with hot water kept continuously agitated, and its rate of cooling, at a constant temperature of the air in the chamber, was found for the vessel when bare and when covered with various coatings. The cooling chamber was double, having a water-jacket; internally, it was 31.5 inches in diameter and 39.4 inches high.

Péclet's general conclusions as to the heat emitted by radiation are:

"The quantity of heat, per unit of surface and of time, emitted by radiation is independent of the size and form of the body—if the surface of the latter has no re-entrant portions (since radiation is a mutual action, and the adjacent surfaces of a return-bend, for example, would ra-

diate to each other); this quantity depends only on the nature of the surface, on the excess of its temperature above that of the surrounding objects, and on the absolute value of the temperature of the latter."

His formula for the heat lost by radiation is:

$$R = 124.72\ K\ a^{\theta}(a^{t} - 1),$$

in which R is the quantity of heat in calories (large) emitted by radiation per square metre of surface per hour, t is the temperature-difference between this surface and the surrounding objects, θ is the temperature of the latter—i. e., usually that of the air—a is a constant having, for metric units, the value 1.0077, and K, the radiation factor, is a number whose size depends on the nature of the radiating surface. The temperatures are in degrees C.

With regard to the abstraction of heat by conduction to the air and the convection currents formed therein, Péclet states:

"The loss of heat which is due to the contact of the air is independent of the nature of the surface of the body and of the temperature of the surrounding air; it depends only on the excess of the temperature of the body above that of the surrounding air and upon the form and dimensions of the body.'

His formula for the loss of heat by the contact of air undisturbed by accidental currents is:

$$A = .552\ K^{1}\ t^{\,1.233}$$

in which A is the quantity of heat in calories (large) thus transmitted per square metre of surface per hour, t is the temperature-difference between the surface and the surrounding air, and K^1 is a number whose size varies with the form and dimensions of the body. The formula applies only to air at atmospheric pressure.

The total heat loss of a cooling body is then:

$$M = R + A.$$

For horizontal cylinders:

$$K^{1} = .421 + .308/r,$$

in which r is the radius in inches.

For vertical cylinders:

$$K^{1} = \left(.149 + \frac{.0443}{\sqrt{r}}\right)\left(2.43 + \frac{1.585}{\sqrt{R}}\right)$$

in which r is the radius in inches and h is the height in feet.

For cylinders inclined at the angle α to the horizontal:

$$K^{1} = K^{1}\ (\text{hor.}\ \cos\alpha + K^{1}\ (\text{vert.})\ \sin\alpha.$$

In so far as our present knowledge of the subject extends, there can be no question of the correctness of Péclet's general conclusions as to the characteristics which influence the losses by radiation and conduction, except that he considers both of the latter as independent of the composition of the body—an assumption which, so far as the theory of Stefan's law is concerned, is certainly not true of radiation, and, unless the action of internal conduction be disregarded, cannot be correct for external conduction

With regard to the accuracy of his two fundamental formulæ, it should be observed that they are essentially those of Dulong and Petit, the correctness of whose results, within their temperature-limits, has been generally admitted; and, further, that Péclet verified them experimentally for temperature differences ranging from 45 degrees to 117 degrees F. His formula for K^1 for horizontal cylinders gives a more rapid decrease with increasing diameter for the value of that coefficient than the majority of test results appear to warrant, although his view that there is such a decrease in the heat loss—owing to the reduced area of cooling surface per unit area of cross-section of the pipe and to the retardation of convection currents from the lower half of the pipe by the greater radius and lessened convexity of the latter—is fully sustained by practical experience.

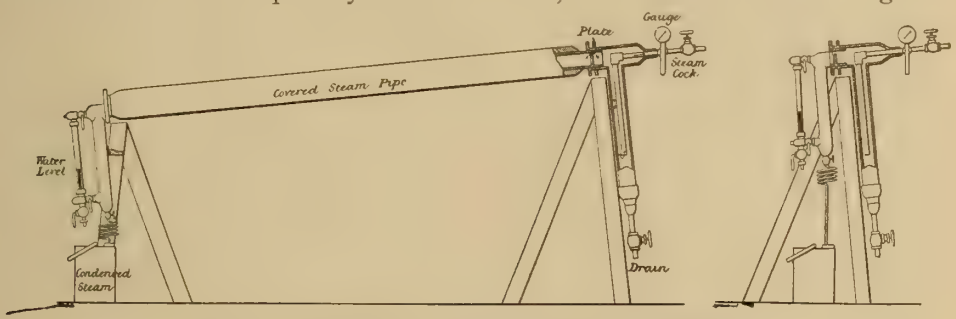
The formula for the heat lost by radiation shows that the radiating power of a body increases somewhat slowly with the temperature of the surroundings and very rapidly with

the temperature-difference between the body and the air. Thus, for the same temperature-difference, the heat radiated at an air temperature of 194 degrees is 78 per cent. greater than at 59 degrees, while if, at 59 degrees, the temperature difference be increased five times, from 72 degrees to 360 degrees, the heat loss will be more than ten times greater. The marked advantage of a polished casing for pipe coverings is indicated by Péclet's values for the radiation factor K. Thus, for ordinary sheet iron, his table gives K as .568; for polished sheet iron, .092. From his formula for the loss by air contact, it will be seen that the quantity of heat abstracted by conduction is considerably smaller than the corresponding loss by radiation; and, further, that the former loss grows much more slowly than the latter with increase in temperature-difference. For example, the increase per degree in the radiation loss at a difference of 360 degrees is 5.181 B. T. U.; that at 72 degrees is 1.518—a ratio of 3.41; the similar ratio for the conduction loss is 1.44.

While Péclet's formulæ are too complex for ready service in calculation, he has made their use relatively simple by various tables. Thus, he tabulated—for an air-temperature of 15 degrees C. and for temperature-differences at intervals of 10 degrees in the range between 10 degrees and 250 degrees C.—the numerical values of the product of all the factors except K in the right-hand member of the formula for R, giving, in addition, the factors by which these coefficients are to be multiplied for other air temperatures, and also the values of K for surfaces of various characters. He prepared, also, similar tables for use in place of the formulæ for A and K^1.

TEST APPARATUS FOR SATURATED STEAM

The methods used to determine the heat losses of steam pipes have differed widely in their completeness and their degree of accuracy. Among the best of the apparatus employed for this purpose is that designed by Professor T. Hudson Beare, M. Inst. C. E., which is illustrated in Figs. 1 and 2. Messrs. Bolam and Grieve state (*Engineering*, August 7, 1903) as to this apparatus:



FIGS. 1 AND 2.—TESTING APPARATUS OF PROF. T. HUDSON BEARE

"The piping used is a piece of ordinary 3-inch wrought-iron steam piping, 8 feet 10⅝ inches long, with a mean external diameter of 3.53 inches, giving a total external area of uncovered pipe surface under test of 8.132 square feet. Steam from the boiler enters at the right-hand end of the apparatus, passing down through the internal pipe shown in the figure. This arrangement was adopted to lessen the chance of any suspended moisture being carried forward into the experimental pipe. As an additional precaution, the ¼-inch diameter opening, by which the steam enters the experimental pipe from this vertical pipe, was bored in the top of the diaphragm plate placed between the two pipes. The actual path of the steam is shown in the figure

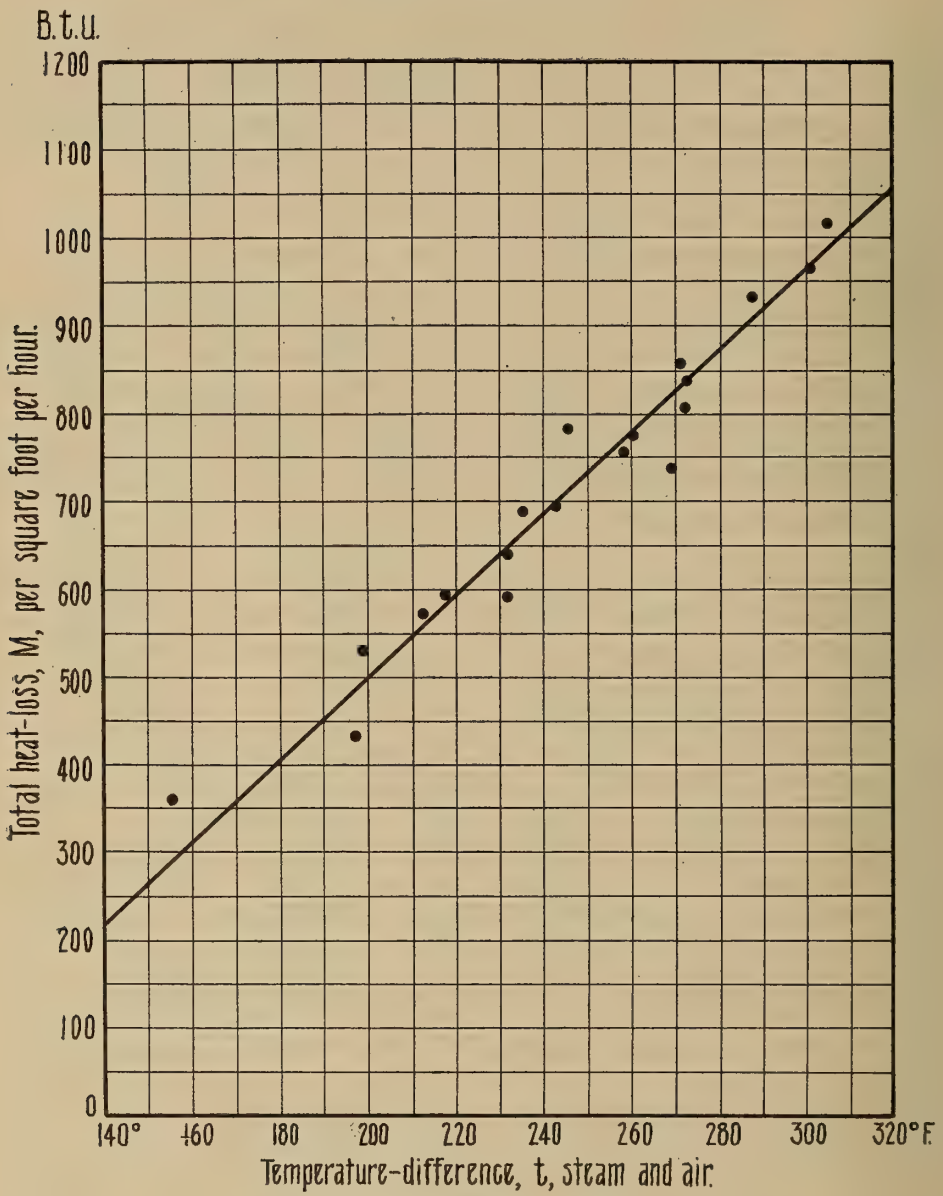


FIG. 3.—HEAT LOSSES FROM BARE PIPE

by arrows. It was, therefore, extremely improbable that any priming water or other moisture present with the steam in the vertical pipe would find its way into the experimental pipe. Any moisture collecting in the vertical pipe was drawn off by a drain-cock at the base; and, throughout all the experiments this cock was so adjusted that steam was continually issuing from it. The pressure of the steam, as it entered the experimental pipe, was recorded by a gauge which had been verified and was regulated by a stop-cock.

"The experimental pipe sloped down from right to left, so that all the condensed steam was collected at the left-hand end in a vertical pipe fitted with a gauge glass, and

throughout the experiments the condensed steam was kept at a constant level in this vertical pipe by means of the control secured by the small cock at the base. From this cock the condensed steam escaped through a copper worm and piece of rubber tubing, the latter dipping into a vessel filled with cold water, marked 'condensed steam' in the figure. By this means any loss due to vapour being given off from the condensed steam as it issued was avoided. By weighing this vessel at the beginning and end of any interval of time, the amount of steam condensed during that interval was accurately known.

* * * "Evidently, in any experiment, part of the condensation is due to the flanges and vertical pipes, etc., at the ends of the apparatus, and to obtain correcting factors to apply to the results of the main experiments this condensation had to be determined. For this purpose, the pipe was disconnected, the fittings were connected up as shown in Fig. 2, and a series of experiments at various steam pressures was carried out under exactly the same conditions as those existing when the experiments were made with the covered pipe in position."

HEAT LOSSES OF BARE PIPES CONVEYING SATURATED STEAM

Table 1 gives the principal data of available tests on saturated steam in bare pipes, arranged in the order of their temperature-differences. The steam was, in all cases, motionless, except for the flow necessary to replace the condensate; the heat loss was assumed to be the latent heat of the amount of the condensate which was properly chargeable to the pipe under test, this condensate being considered as discharged at the temperature of the steam; the loss per square foot of outer surface of pipe, as given in the table, refers to that surface only and not to the flanges and valve chambers of a steam pipe in actual service, for whose heat losses additional allowance should be made. In these tests the internal diameter of the pipe ranged from 2 to 8 inches; the absolute steam pressure from 17.7 to 195.9 pounds per square inch; the average temperature-difference between the steam and the air was 246.2 degrees F., and the corresponding loss of heat per square foot per hour was 714.91 B. T. U., or 2.9 B. T. U. per degree of temperature-difference.

In Fig. 3 the heat losses of these nineteen tests are plotted on the temperature-differences as abscissæ. It will be seen that the losses increase with the temperature-difference and follow, in close approximation, a straight line whose equation is:

$$M = 4.635\ (t - 140) + 222,$$

in which M is the total heat loss in B. T. U. per square foot of outer surface per hour and t is the temperature-difference between the steam and the air in degrees F.

TABLE 1

HEAT LOSSES OF SATURATED STEAM IN BARE PIPES.

Test No.	Metal.	Pipe Diam. External, Ins.	Steam Press. Lb., Abs.	Temp., °F. Steam.	Temp., °F. Air.	Temp.-Diff. Steam and Air, Deg. F.	Heat-Loss Per Sq. Ft. Per Hour B.T.U.
1	C. I.	6.2	74.7	307.1	76.1	231.	596.02
2	C. I.	2.39	74.2	306.6	75.4	231.2	642.74
3	C. I.	2.39	94.7	323.7	50.5	273.2	841.46
4	C. I.	2.39	164.7	365.7	60.5	305.2	1019.37
5	W. I.	3.53	17.7	221.5	64.8	156.7	360.63
6	W. I.	3.53	39.7	266.7	69.2	197.5	433.9
7	W. I.	6.3	47.4	277.3	78.3	199.	528.41
8	W. I.	3	45.1	274.4	61	213.4	574.16
9	W. I.	3.53	54.7	286.5	68.5	218	595.7
10	W. I.	6.3	96	324.7	89.1	235.6	687.45
11	W. I.	3.53	73.7	306.2	62.6	243.6	697.19
12	W. I.	3.53	884.7	315.8	69	246.8	785.47
13	W. I.	3	93.7	322.9	63	259.9	753.87
14	W. I.	3.53	100.7	328.1	68	260.1	775.9
15	W. I.	8.5	125.2	344.3	75.5	268.8	728.45
16	W. I.	3.53	114.7	337.7	65.3	272.4	859.6
17	W. I.	7.64	164	365.4	92.3	273.1	807.4
18	W. I.	6.3	185.9	375.4	87.1	288.3	933.2
19	W. I.	3	185.5	375.3	71.1	304.2	962.35
Average			95.1	317.1	70.9	246.22	714.91

SOME CAUSES FOR THE LACK OF AGREEMENT BETWEEN TEST RESULTS AND THE HEAT LOSSES COMPUTED THEORETICALLY

It is evident that heat-loss formulæ, such as those of Péclet—derived from the results of rigid laboratory experiments on apparatus of limited size and under wholly controllable conditions as to air currents and the exact measurement of the heat abstracted — although giving results which, within the limitations of the

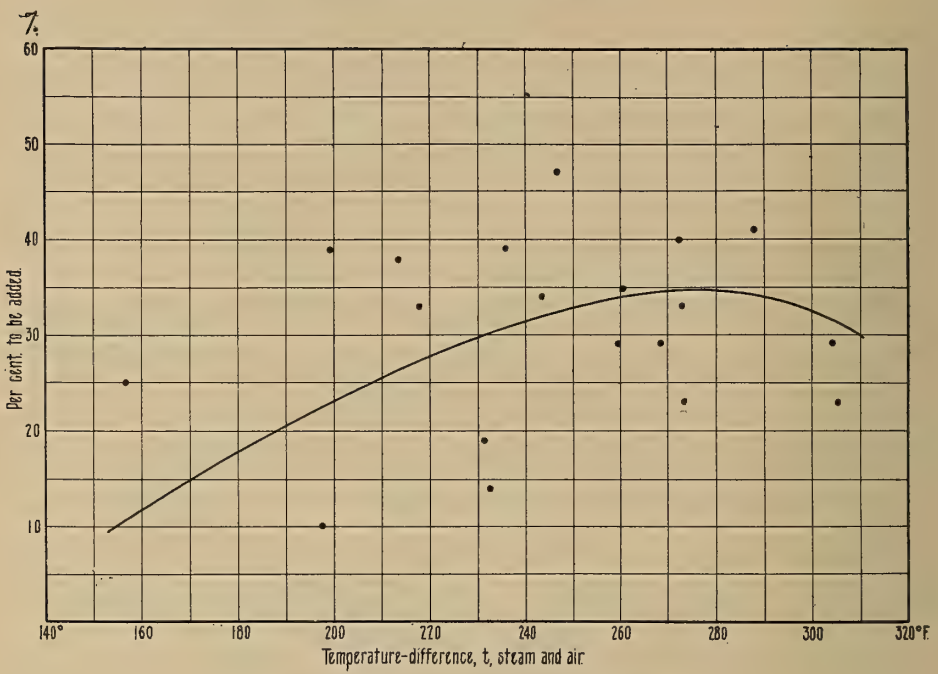


FIG. 4.—ACTUAL AND COMPUTED HEAT LOSSES

origin of the formulæ, have all necessary accuracy, may still, when applied under the varying conditions of practice, indicate heat losses which will at times prove to be wide of the mark.

While the majority of the tests of Table 1 were not made upon steam pipes forming part of an actual plant, none of them was conducted under conditions as to accuracy which can be considered as comparable with those of Péclet's experiments. Some discrepancy between computed and actual results is, therefore, to be expected. Such a comparison is given in Table 2, where the excess of the actual over the computed losses for the tests in question average about 30 per cent. The principal reasons for this lack of agreement are, as to tests in general:

(*a*) *Air currents not due to convection.* This is a disturbing condition which exists to a greater or less extent in all tests not conducted under the most exacting laboratory conditions. While the effect of such occasional currents cannot be estimated definitely, it may often be considerable. Mollier, for air-speeds per second of 2, 4 and 6 metres, found an increase in heat transmission of 1.3, 1.8 and 2.2 times, respectively, as compared with still air. Valerius gives 0.22 for air in a confined space, and 0.28 to 0.33 for free air, as values of the conduction factor K^1, per square metre per hour. Professor Norton shows from his tests on bare pipes filled with hot oil the effect of the surroundings and position of the pipe in the following table, in which the heat loss is stated in B. T. U. per square feet per minute at a temperature of the oil corresponding with that of steam at 200 pounds pressure gauge:

Condition and Position of Pipe	Heat Loss
1. Standard condition, hung in centre of room...	13.84
2. Near brick wall between windows.....	14.26
3. Hung horizontally in centre of room.....	12.06
4. Vertical 10-inch pipe 36 inches long.....	13.48
Vertical 10-inch pipe 18 inches long.....	14.42
5. Vertical 18 inches long 10 inches diameter....	14.42
Vertical 18 inches long 4 inches diameter.....	15.20
6. 8-inch pipe in draught from electric fan.....	20.10

(*b*) *Inaccurate measurement of the amount of the condensate which is properly chargeable to heat loss from the pipe under test.* In general, this

source of error exists in but small degree in laboratory tests, since the condensate produced by the attachments of the test pipe is, as a rule, carefully estimated; with tests of pipes in service, however, the conditions as to this have often been very different, leading to misleading results. Thus, defective action of the separator will reduce the apparent amount of the condensate, since a part of the latter will pass on, held in suspension by the steam; the leakage of steam traps will allow steam to filter through, to be later condensed, thus unduly increasing the amount of the condensate; finally, while separators are usually covered, drip-pipes and traps frequently are not, and the effect of the combined cooling surfaces of the two latter in adding to the weight of steam condensed may be marked.

TABLE 2

RATIOS OF ACTUAL HEAT-LOSSES TO THOSE COMPUTED BY PECLET'S FORMULAE: VALUES OF THE HEAT-TRANSMISSION COEFFICIENT K_3

Test No.	Temp.-diff. Steam and Air, °F.	Heat Loss per Sq. Ft. per Hour, B. T. U For Total Temp.-diff. Actual.	Péclet.	Ratio.	per 1° F. Temp.-Diff. (K_3).
1	231	596.02	502.44	1.19	2.58
2	231.2	642.74	566.38	1.14	2.78
3	273.2	841.46	681.05	1.23	3.08
4	305.2	1019.37	827.16	1.23	3.34
5	156.7	360.63	287.82	1.25	2.301
6	197.5	433.9	393.35	1.10	2.197
7	199	528.41	379.13	1.39	2.655
8	213.4	574.16	438.69	1.38	2.691
9	218.	595.7	448.41	1.33	2.732
10	235.6	687.45	492.65	1.39	2 918
11	243.6	697.19	519.21	1.34	2.862
12	246.8	785.4	534.24	1.47	3.182
13	259.9	753.87	582.13	1.29	2.901
14	260.1	775.9	576.24	1.35	2.983
15	268.8	728.45	563.49	1.29	2.71
16	272.4	859.6	613.39	1.40	3.15(
17	273.1	807.4	606.55	1.33	2.956
18	288.3	933.2	660.77	1.41	3.237
19	304.2	962.35	748.31	1.29	3.163
Avgs.	246.22	714.91		1.305	2.864

For example, Richter, in investigating the question as to whether superheated steam could entrain water, considered the results of thirty-two of the more important tests in which the degree of superheat was apparently great enough to prevent the formation of condensate in the pipe. He assumed an average amount of cooling surface for the drips and traps, and found that, in seventeen of these tests, this assumed surface was sufficient to produce the entire amount of the condensate reported as chargeable to the steam pipe.

(*c*) *Unsuitable test apparatus.* Some experimenters, in designing test apparatus, seem to have disregarded the fact that radiation is a mutual action and, further, that convection currents from two adjacent heated bodies may conflict. Any apparatus for this purpose whose operation involves the simultaneous cooling of two or more pipes, relatively close together and without effective screens between them, is incapable of giving accurate results.

(*d*) *Minor causes.* Other reasons for the discrepancy between theory and practice in estimating the heat losses of steam pipes are: inaccurate measurement of the loss due to flanges, valve chambers, etc.; taking the temperature of the outer surface of the pipe as that of saturated steam, and relying on surface measurements of pipe metal or covering, this method being untrustworthy.

CORRECTION FROM PRACTICE TO BE APPLIED TO THE HEAT LOSSES OF BARE PIPES CONVEYING SATURATED STEAM, AS COMPUTED BY PÉCLET'S FORMULÆ

The excesses of the actual over the computed losses, as shown in Column 5, Table 2, have been plotted as percentages in Fig. 4 on the corresponding temperature differences and a mean curve drawn. In estimating the heat loss of a bare pipe, at a given temperature-difference and under average conditions, the loss, as computed by Péclet's formulæ, should be increased by the percentage given by this curve.

This method is far from being free from objections, since the percentages plotted include not only the effect of air currents, but the possible errors of investigators as to the amount of the condensate charged to the pipe. It is, however, the best means available of making a reasonable approximation. It will be understood that this curve applies only to bare pipes between 2 inches and 8 inches in diameter.

EFFECT OF DIAMETER OF PIPE ON HEAT LOSS

These tests give somewhat discordant results as to the effect of the pipe diameter on the heat loss, although in general the loss decreases as the diameter increases, in accordance with Péclet's view. In computing the value of the conduction factor K^1, the radiation loss R, per square foot per hour, was found, and this deducted from the corresponding total loss gave the conduction loss A. The latter loss was then divided by the coefficient of K^1 as tabulated by Péclet, the quotient being the value of K^1. The mean values thus obtained are:

Internal Diameter of Pipe, Inches.	Conduction Factor, K^1
2	.977
2.76	1.006
3	.981
5	.758
5.91	1.007
7.09	.915
8	.84

CONDITIONS AFFECTING THE LOSS OF HEAT OF SUPERHEATED STEAM DURING TRANSMISSION

The pipe losses of superheated steam are: the pressure loss, the loss of temperature, and partial condensation, if the degree of superheat be low; the first of these is not essentially a heat loss. Tests on pipes conveying superheated steam are much more difficult in execution than the corresponding tests with saturated steam. The main reason for this is that, in the former case, the velocity of the steam is a factor in producing the heat loss, and hence tests should be made only on moving steam and at the velocity at which it is desired to find the heat loss. This condition makes the problem complex. It may be well to consider its factors:

(*a*) *Absolute and proportionate heat losses.* The absolute heat loss of a steam pipe is the loss per square foot per hour from the outer surface. What has been termed, somewhat loosely, the proportionate loss is the loss of heat per pound of steam transmitted. If there be two uncovered pipes of the same diameter conveying saturated steam of the same pressure and quality, but with the velocity of the steam differing in the two cases, the absolute loss of one pipe will be the same as that of the other, but the proportionate loss will evidently be less for the pipe in which the steam moves at the higher velocity. Assume now that the pipes convey superheated steam, the pressure and temperature at entrance being the same in each pipe, but the velocities differing; then, while there will still be a reduction in the proportionate losses at the higher velocity, the absolute losses will not be the same for the reasons given below.

(*b*) *High and low degrees of superheat.* According to the investigations of Richter and Eberle, highly superheated steam simply loses some of its superheat during transmission and no part of it is condensed. The only method of absolute accuracy for determining the heat losses of such steam is to find the average quality at entrance to, and exit from, the pipe—a process which is difficult, since it involves temperature measurements at various points in the cross-section of the column of steam at these two locations.

When the degree of superheat is low, an absolutely accurate determination of the heat loss is practically impossible, for, although the steam temperatures may be observed, as before, the action is further complicated by the fact that a section of the pipe will be cooled below the temperature of saturation, a portion of the steam will be condensed, some of this condensate will be entrained by the swiftly moving steam, and a part of it will be carried through the separator, thus escaping measurement.

(*c*) *Effect of steam velocity.* The temperature of the pipe is the main factor in causing the heat loss; while this temperature depends primarily on that of the steam, it is also influenced markedly by the velocity of the steam, whose effects are somewhat complex. Thus:

At high steam velocity, the steam

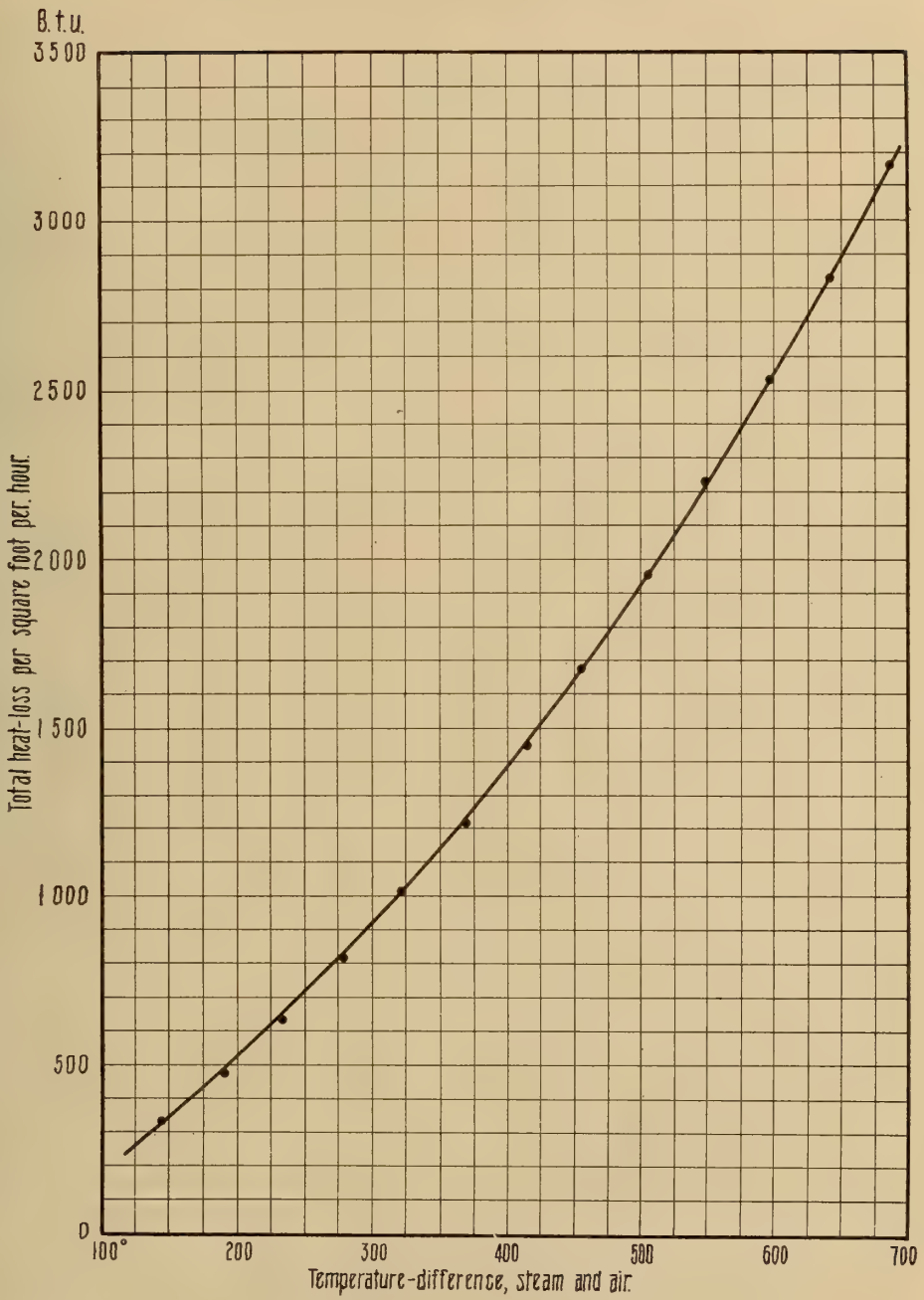


FIG. 5.—HEAT LOSSES WITH SUPERHEATED STEAM

in its swift motion has little time to cool, and hence the proportionate loss is less than at low speed; but the temperature-fall from the centre to the circumference of the pipe must also be less and, as a consequence, the temperature of the pipe is higher, the temperature-difference between it and the air is greater, and the absolute loss more than at low velocity.

At low steam velocity, these effects are reversed. The steam has more time to cool and the proportionate loss is greater; but the fall of temperature across the cross-section of the column of steam is greater also, and hence the temperature of the pipe, the temperature-difference between the steam and the air, and the absolute loss are less.

HEAT LOSSES OF BARE PIPES CONVEYING SUPERHEATED STEAM PER SQUARE FOOT OF OUTER SURFACE OF PIPE PER HOUR

It has been shown that the heat losses of a bare pipe depend primarily on the temperature of the latter, and that this temperature and the coefficient of external conductivity from the steam to the pipe depend, with superheated steam, not only on the temperature of the latter, but upon its velocity. It is apparent that, with the same steam temperature, there may thus be absolute heat losses which will differ widely at different velocities of the steam. Hence, tests based on steam temperature only, or on steam velocity only, are of no service.

Owing to these conditions, which make the number of possible combinations indefinitely large, and to the lack of experiments on the subject, it is not possible to assemble test results which can be plotted, like Fig. 3, as a general curve covering all cases within their temperature limits. The only available tests on bare pipes which were made with sufficient accuracy to permit definite deductions are those conducted by Eberle under the auspices of the Verein deutscher Ingenieure. These tests were made on a pipe 70 mm. (2.76 inches) internal diameter and 87 feet 2 inches long, first at a steam velocity of 5,906 feet per minute, and again at velocities between 1,772 and 1,969 feet per minute; the absolute (average) pressure of the steam was, in both series, about 96 pounds per square inch; the steam temperatures (mean) were 578.7 and 456.3 degrees F., respectively; the air temperature was 51.8 degrees F.

On the basis of the results of the first series of these tests, Eberle presents the data given below in Table 3 as fairly representing the action of superheated steam for the temperature range tabulated, at a velocity of 4,920 feet per minute, and with a value of 30.75 for k_1, the coefficient of external conductivity of the steam to the pipe metal. The absolute heat losses given in this table are plotted in Fig. 5 on the temperature-differences as abscissæ.

TABLE 3.

HEAT-LOSSES OF BARE PIPES TRANSMITTING SUPERHEATED STEAM; STEAM VELOCITY, 4,920 FEET PER MINUTE; COEFFICIENT OF EXTERNAL CONDUCTIVITY, STEAM TO AIR EQUALS 30.75; AIR-TEMPERATURE, 68° F.

Temperature F. of		Temperature-Diff. Between Steam and		Heat-Loss per Sq. Ft. of Outer Surface of Pipe per Hour,
Steam.	Pipe.	Air.	Pipe.	B. T. U.
212	201.2	144	10.8	343
257	240.8	189	16.2	483
302	280.4	234	21.6	642
347	320	279	27	823
392	359.6	324	32.4	1018
437	397.4	369	39.6	1225
482	435.2	414	46.8	1450
527	471.2	459	55.8	1697
572	509	504	63	1956
617	545	549	72	2232
662	579.2	594	82.8	2531
707	615.2	639	91.8	2841
752	649.4	684	102.6	3170

With regard to the data of Table 3, it should be observed that the tests were made on one pipe only, thus preventing investigation of the effect of change in pipe diameter on the heat losses; and that the temperature of the pipe and its heat losses per square foot of outer surface per hour were found from the assumed value for k_1, and by applying to the pipe the same methods as those used for saturated steam, thus assuming that, for the same pipe temperature, the heat emissivities of stationary saturated steam and of superheated steam at the velocity given above are identical. These assumptions necessarily affect the absolute accuracy of the results; but their effects are of minor importance, and the data may be accepted as giving general indications of value as to the action of superheated steam within the limits covered by the table.

THE EXPLOSION GAS TURBINE

By Henry Harrison Suplee

IN the article upon the gas turbine contributed to the issue of this magazine for January, 1907, by the late M. Réné Armengaud upon the subject of the gas turbine, there appeared a brief mention of the so-called explosion gas turbine, a machine quite different from the turbines in which the products of combustion under pressure are directed in a continuous stream upon the revolving wheel. At that time the explosion turbine was considered as little more than a toy, and it is but recently that it has been developed into a practical machine.

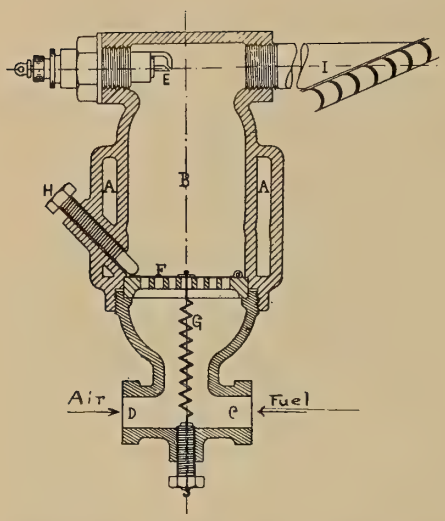
During the past year there has been built in Paris, by M. Karavodine, an explosion gas turbine developing about 2 horse-power, and operating with regularity and success; and from recent tests of this machine by M. Alfred Barbezat we are able to give some quantitative data concerning its performance.

The explosion turbine depends for its operation upon a sequence of events similar to that which obtained in the old Otto & Langen free-piston engine, the successor of the Lenoir gas engine, and the immediate predecessor of the Otto silent engine, which utilized the cycle of Beau de Rochas. It will be remembered that the Otto & Langan engine had a tall, vertical cylinder, and that when the mixed charge of gas and air was ignited it drove the piston to the top of the cylinder, and that the partial vacuum which followed the explosion under the piston sucked the latter down again, this latter being the power stroke, the piston being connected to the shaft by a ratchet and pawl movement, which permitted a free upward stroke.

In the case of the explosion turbine the charge of gas or hydrocarbon vapour is ignited in a combustion chamber, and the force of the explosion drives the contents out through a nozzle against the blades of the turbine wheel. The partial vacuum which immediately follows the explosion draws in a fresh charge through a valve which opens inward, and the ignition of this charge causes a fresh explosion, this operation being repeated almost continuously, so that a very rapid succession of impulses upon the wheel keeps it in motion. In practice it is found that the explosions follow each other many times a second, so that the effect is practically a continuous one. It will be seen that this device does not involve the use of any compressor, and thus avoids one of the chief difficulties in the design of a practical gas turbine; but for the same reason it is a non-compression machine, and thus it cannot be expected to attain as high a thermal efficiency as an engine operating with high compression.

The Karavodine explosion gas turbine tested by M. Barbezat was provided with four explosion chambers, the products of the explosions being directed through four separate nozzles upon a single turbine wheel. This wheel was of the De Laval type, about 6 inches in diameter (150 centimetres), carried upon a flexible shaft, and fitted with a Prony brake.

The general construction of the explosion chambers is shown in the illustration. The body of the chamber *B* is composed of cast iron and provided with a water jacket *A*, which does not extend all the way to the top, thus permitting the portion



COMBUSTION CHAMBER OF THE KARAVODINE TURBINE

nearest the discharge nozzle to become heated. At the lower end there is provided an opening *C* for the entrance of the fuel, either gas or hydrocarbon vapour; also, an opposite opening *D* for the entrance of air. These openings are both provided with throttle-valves, not shown in the illustration, by means of which the proportions of air and gas may be regulated. At *E* is an electric ignition plug, and at *F* is a plate steel valve, opening inward, and held to its seat by a spiral spring *G*, its lift being regulated by a set-screw *H*. The discharge nozzle is shown at *I*, and also a portion of the perimeter of the turbine wheel.

In starting the machine the air opening *D* is closed by its throttle valve and a blast of air is blown through *C*, the explosive mixture being ignited by a spark at *E*. After the first explosion the air entrance *D* is opened and a sort of pulsometer action follows, thus: After each explosion there follows a depression, or partial vacuum, which acts to draw air and hydrocarbon vapour or gas into the chamber *B*, lifting the valve *F*. This mixture is instantly ignited by the spark at *E*, and another explosion follows, to be again followed by another suction, and so on indefinitely. After a short time the upper part of the chamber *B* becomes so hot that the igniter *E* may be shut off, the charge being exploded by the heat of the chamber. The nozzle *I* is made rather long, and it is found that the friction against the walls and the inertia of its contents prevent any material negative or back suction through it, so that the chamber *B* is filled at every stroke almost entirely from the air and gas openings below.

When the tension on the spring *G* and the lift of the valve *F* are both carefully adjusted this simple device will run for hours without miss or interruption, the explosions following each other so closely as to make practically a continuous discharge upon the turbine wheel.

In order to investigate the action and pressure in this explosion chamber, a special form of recording gauge was made. The pressure in the chamber acted upon a thin steel diaphragm, of which the deflections actuated a small mirror, throwing a beam of light upon a rapidly-moving, sensitive film. The result was the production of a curve of the sine type, in which the ordinates represent pressure and the abscissas show time.

In the diagram shown in the illustration the solid curved line is made up from the average of a number of diagrams, while the dotted line shows the one which deviated most widely from the mean. During the period *A, E* there was a partial vacuum in the chamber, and the mixed charge was drawn in. From *E* to *D* the pressure of the explosion occurred, and the contents of the chamber were discharged upon the wheel. The ignition began at *B*, and the force of the explosion reached its maximum at *C*, while the period *A, B* includes the inertia action of the gases. The diagram shows that a complete oscillation required 0.026 part of a second, corresponding to between 38 and 39 explosions per second. The mean pressure *A, F* in the diagram was 1.139 kilograms per square centi-

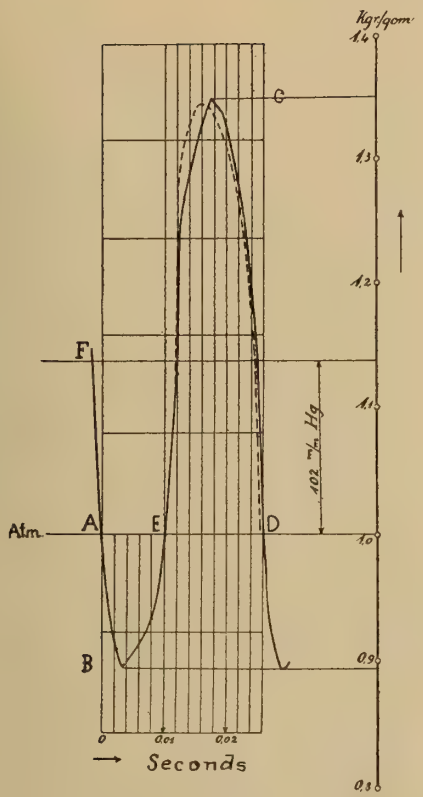


DIAGRAM OF THE EXPLOSION TURBINE

metre (absolute), or about 16¼ pounds per square inch, the maximum force of the explosion being 1.345 kilogrammes, or about 19 pounds per square inch. The lowest suction pressure was 0.890 kilogramme, or 12.6 pounds absolute, thus giving a negative pressure of about 2 pounds to draw the charge in, and a discharge pressure of between 4 and 5 pounds on the wheel.

In the machine tested by M. Barbezat the volume of one chamber was 230 cubic centimetres. Each nozzle was 3 metres long and 16 millimetres bore, slightly curved at the end to conform to the shape of the wheel. The wheel itself was 150 millimetres in diameter, or 5.9 inches, and made 10,000 revolutions per minute, corresponding to a perimeter velocity of 78.5 metres, or about 258 feet per second.

At the same time the above diagrams were taken the amount of air drawn into the four chambers was measured by a meter, and the quantity of gasolene consumed was measured, while the power developed was determined by the Prony brake. The data and results were as follows:

Air consumed per hour, 62.5 cubic metres = 80 kg.

Gasoline, 6.5 litres = 4.7 kg.

Length of brake arm, 46.4 centimetres.

Weight on brake, 248 grammes.

Speed, 10,000 revolutions per minute.

From these figures the brake power works out 1.6 horse-power, and as the wheel and journal friction was determined at 0.5 horse-power, the actual indicated power was 2.1 horse-power. This gives a fuel consumption of 2.24 kilogrammes of gasoline per horse-power-hour, which is very fair for such a small machine, being only about one-third greater than that of the old Lenoir gas engine.

In considering the availability of such a machine there are a number of other considerations than the mere fuel consumption. The continuous turning effort is often most desirable, and when it is considered that the wheel of this machine was less than 6 inches in diameter, the possibilities of such an apparatus may become evident. The absence of a compressor and corresponding reduction in weight and size give such a machine marked advantages over the combustion turbine, in which the compressor is much larger than the turbine itself, and even if the fuel consumption is as high as indicated above.

PRESENT METHODS OF EDUCATION

By Julian Chase Smallwood

BROADLY speaking, education should follow three paths: first, the imparting of knowledge; second, the repetition of mental processes for the sake of practice; and third, the development of ability to reason. The first division is the one most satisfactorily handled both in the preparatory and technical schools, so much so that our school boy of to-day knows more than Galileo; the second is insisted upon only by the most clear-seeing educators; while the third is scarcely attempted at all. Which is the most important to the student?

During his education the modern school boy is like a keg with a funnel in its bung-hole to receive the liquid poured into it. He is in a passively receptive state, taking no active part in the proceedings, except that he supports the funnel. This constitutes our teaching of knowledge. He is made to remember facts. When he has passed his examination, more facts are poured in, often largely displacing the old ones. He learns rules by heart, he memorizes the propositions of Euclid, and, in fact, "knows the book." In the technical school it is the same way. He can, if he is what is called a good student, deduce the equations for the elastic curves of the different beams discussed in the text and apply the formulas; he knows the advantages and disadvantages of a centrally-packed outside plunger-pump, and so forth. He has memorized these things, and this memory is knowledge.

So much, I think, will be granted, and so much is necessary and good. Now, how about the practice? How many technically-trained men can accurately add six columns, of six figures each, at the first attempt? How many men who have passed a rigid entrance examination in English can write a page of correct English? The proportion is deplorably small. Yet the practice obtained in schools is supposed to teach these things. It is the same in the more advanced studies. In algebra, calculus, etc., it is customary to solve many problems; but our methods of instruction do not enable the student to do so accurately and feel sure of results. In many cases he knows the answer and obtains a number of incorrect ones before the right one is reached—sometimes by an erroneous process. When the correct answer is not previously known, it is quite customary for a number of students to compare results until a common one is obtained. Thus they do not realize in school how inaccurate they are.

We come, then, to the third branch of education, which, to my mind, is the most important. This should train the student to think independently and develop or create habits of mental investigation and analysis. It is astonishing to me that, with rare exceptions, our technical schools almost entirely disregard this branch in the ordinary courses of instruction. Perhaps the closest approach to it is made in the laboratory courses in analytical chemistry; for such courses consist of a series of real problems, to solve which it is essentially necessary that the student use his reason. More-

over, he cannot let lack of confidence in his ability control his judgment to the same extent as in other studies, since he can have no foreknowledge of the answers.

The relative importance of these three divisions of instruction would seem to me to require no demonstration, were it not for the fact that our schools, in their practice, reverse the order. I hope, therefore, that the following support of my argument will be forgiven by the more enlightened of my readers.

Everyone who has been graduated from a technical school has witnessed the wide variations in the successes of his classmates in practical work. Success may easily be attributed to natural causes, and it is not difficult to understand the success of him who was dull in college. Thus, one only ordinarily gifted has become environed with the kind of work necessary to the best development of his talents; while another, actually stupid as a scholar, uses his weak technical knowledge as a basis for his business ability. Still another may climb the ladder by will and determination to push others aside, that he may pass. We have all met this kind. Such cases we can explain satisfactorily to ourselves; but there is another at which, I think, we all have cause at some moment to stop and wonder. He who was a good scholar and thought highly of by his instructors, fails in his professional career, though he tries as earnestly and has as high ambition as his fellows. He never does better than ordinarily well. What is the reason for it? I think it is that such a man is not fit for his work. "But," it may be said, "he has been sent from his university with honors—his university has, in a measure, guaranteed his capabilities." The answer is that an educational system which permits this is at fault. And if it permits this it allows still worse. In every class there is at least one man gifted with an exceptional memory, who with little effort satisfies the requirements. I know such a one as a classmate who, by subterfuge, attended not more than one-fourth of the hours prescribed, and "crammed" for each examination only the night before. He could get the solid matter from a text-book in a very few hours and retain it for a very few more—sufficient to satisfy his examiners. He was graduated well up in his class, but knew practically nothing of engineering.

Is it not a crying shame, then, that such men should be vouched for on parchment as engineers? Is not the only conclusion possible from these obvious facts that there is something wrong with our educational system? If so much is admitted, it will then be asked, "What can be done about it?" If we are prepared to recognize the fact that we make as great a mistake in ladling out education without discriminating regard to individual needs as we should were we to attempt to nourish all children with the same food, we shall begin to reach a solution of the problem.

In the foregoing I have led up to two principal faults in our present régime which I wish to emphasize in this discussion: first, the lack of consideration of that most important branch of education, the cultivating of the ability to reason; and second, the tendency to treat men's minds as a machine for carving wood treats the rough product fed to it, without regard to grain and texture. The remedy for the latter fault lies largely in the practising of a fine discrimination on the part of instructors. Far more individual attention should be given students and a process of segregation should be cautiously followed. That is, students in every course should be classed according to their abilities and the quality of their minds, and each class or squad taught separately. In this way only may those who are less quick be kept from falling hopelessly behind and those brighter ones be saved from retardation. But the important object is to

deal with each mind in the way best calculated to develop it. Minds can no more be nourished with indiscriminate feeling or monotonous diet than can bodies. In accord with growth instruction should be changed, not only in quantity but in kind.

Regarding that other fault of our present methods, the remedy is difficult to apply. It will be argued, too, that students are too much burdened with acquiring knowledge to be further taxed to work independently. Better, then, to decrease the "book learning." The remedy can be applied if it is applied when the mind is young. In my own experience I have found that the progress I sought could not be attained, and could not only because my students through all their scholastic course had been treated as receptacles in which to pour knowledge and were expected to give out nothing. They had suffered lack of early training in the proper direction, and when they came under my control their minds were too strongly bent to be differently inclined. This leads me to believe that first the method of instruction in preparatory schools should be changed so as to train minds to be receptive of what is to come.

In the university, as in the preparatory school, there should never be required a demonstration of a theorem or repetition of text; but the process of thought by which such demonstration is made should be rigidly exacted. Thus, a student should know that a theorem in kinematics, for instance, is proved by a graphic representation of the velocities involved, that instantaneous centres are to be found by applying the principle, and then by the use of similar triangles the relation shown. Knowing this process, he can apply it to a specific case of the same theorem. In such a study as geometry this method can well be followed. The student should first be required to know exactly what his proposition is—according to ordinary methods of instruction, he may be entirely ignorant of it and still give a substantial proof. He should later learn the logical sequence of operations necessary to his proof. That he has learned it may be ascertained by insisting upon his reciting this sequence in his own words. Afterward he should be given to prove not the theorem itself, but the corollaries attached to it. Again, when a formula is to be deduced, the student should never be required to repeat the deduction, but to give the process involved. His next step should be to solve problems to which the formula and its deduction relate, not by applying the formula, but the process by which it was obtained. In fact, there should be no use for, or reference to, formulas. Nothing is more deadening to a proper understanding of a subject, nothing is so detrimental in science to the broadening of the intellect as their use. If the process by which a generic principle is deduced is understood, that process may readily be applied to a specific example.

In conclusion, I would strongly advocate the universal removal of the ban on the use of text-books in examinations. This may startle some of my readers, but a little reflection will show that the plan is entirely practicable. A paper for an examination in a language, for instance, may have a stated time allowed for the answer of each question. Thus, a piece of translation of English into a foreign language may have a time assigned to it such as will allow one moderately fluent in the language to do the work in legible style, but will not permit the looking up of words or tenses in a dictionary or grammar. In scientific subjects questions should be framed to appeal to the intelligence and not the memory of a student. Instead of asking him, for example, what are the advantages and disadvantages of a certain type of machine, he should be questioned concerning the best type to be selected to satisfy given conditions. He will be obliged to use his judg-

ment as well as knowledge to answer such a question. If he has no judgment, he cannot answer it with a cartload of books at his elbow. If he has not knowledge, the element of time forbids his gaining it in the examination room and also answering the question satisfactorily. Again, in purely practical scientific subjects there should be required an exercise of the student's facility to apply facts in the same way that, as an engineer, he will be obliged to do. He should be free to consult his references in the examination room as he would be in the practice of his profession.

The effect of the system I suggest will be two-fold. First, the class-room work will develop independence of thought, impress upon the mind the knowledge that it is necessary that the student gain in a way least taxing to his energies for the result obtained, and give him that reliance upon his own judgment which he must have to become an engineer in the true sense of the word. It will, as well, absolutely disqualify those men whose mental attributes render them incapable of becoming such. Second, the time-limit system and use of reference books will break the hide-bound dependence upon text-books, and at the same time actually test the student's fitness for his future work. He will realize that perforce he must exercise other faculties than that of acquiring knowledge. And, figuratively, when he finds that this staff, which has been of so much assistance to him in walking, does not help him to run, he will lean far less heavily upon it.

THE WEATHERING OF COAL

LOSSES OF FUEL IN STORAGE AND HANDLING AT COALING STATIONS

By Myles Brown

WHEN we consider the enormous quantities of coal which are always kept in store for naval purposes, it seems remarkable that more attention has not been paid to the subject of the weathering of stored coal.

A well-known admiral of the British Navy asserted, in 1903, that, in his experience, a vessel would have to consume more than twice its normal amount of coal per indicated horse-power if the coal had been kept too long in store.

A commander of the United States Navy said, in 1901, that experience has taught the dealers at Trinity Buildings, New York, that every time coal is handled, there is a depreciation of 5 per cent. in value, due to the loss in weight by the breaking up of the coal and the volatilization of the hydro-carbon. It is a fact that the best coal does not disintegrate and powder so quickly as the poorer quality.

It is now generally acknowledged that coal, when exposed to the atmosphere, undergoes some change and deteriorates in value.

Coals vary considerably in their susceptibilities to the action of "weathering." Much depends on the physical structure of coal; the constitution, as well as the constituents, influences the degree of deterioration due to weathering.

Whilst it is generally accepted that coals containing a high percentage of volatile matter are least able to resist the effect of weathering, yet coals having the same chemical composition do not always suffer alike when exposed to the weather. The diverse result is due to the differences in the nature or constitution of the coal.

Coal for naval purposes should have the following points clearly determined by Government experts:

(a) Calorific or heating power;

(b) Percentage of mineral matter;

(c) "Power of resistance" or deterioration when exposed to the weather;

(d) Smoking properties during combustion;

(e) Ultimate and proximate analyses.

The supply of coal perfectly suitable to naval purposes from the Welsh and Scotch coalfields cannot be equaled, or in any degree approached, by any other coalfields in the world.

Nevertheless, even with such an excellent home reserve, it is still of paramount importance to the navy to have on record the qualities of coal available in other coalfields, and also to have comparative records of the Welsh and Scotch coals, so that only the most suitable would be selected for the navy's coal stores.

Reference to the report of the United States fuel testing plant at St. Louis, Mo. (1908) clearly shows the value placed on this class of work by the United States Government.

The act of Congress making appropriation for the sundry service expenses of the Government for the fiscal year ending June 30, 1907, provides.

"For the continuation of the

analyzing and testing of coals, liquids, and other mineral fuel substances belonging to the United States, in order to determine their fuel value, and so forth, under the supervision of the Director of the U. S. Geological Survey, to be immediately available, two hundred and fifty thousand dollars." * * * *

The University of Illinois Bulletin No. 33 gives the result of much important experimental work by S. W. Parr (professor of applied chemistry) and N. D. Hamilton (fellow in chemistry).

Considering the responsibilities of the British Government in relation to the coal supply of the navy at home and abroad, it is of very great importance that the question of fuel testing should have increased attention, and that the Government should own and fully utilize fuel-testing plants both at home and in the British colonies.

Naval engineers may consider that the elaborate practical tests now in vogue are adequate to the present needs of the navy.

But when we consider the anticipated Colonial expansion of the navy, the necessity for a full knowledge of coals other than British is obvious.

It would be interesting to know how much experimental work has been done even with British coals and in the way of determining the structural and chemical qualities of such coals as are found on the Admiralty list, or may in times of stress be required to "coal the navy."

The following data relating to the weathering of various coals are given to show the importance of the subject from a naval point of view:

The writer tested on the spot the effect of weathering on a large stack of Bengal coal. The coal had been exposed for twelve weeks to the climatic conditions usually prevailing in the Bengal province.

The seam from which the coal was taken is noted for its uniformity in quality, and when fresh mined its evaporative power equaled 12.57 pounds. After the stock in question had been exposed for twelve months, two samples, (a) and (b), were taken, (a) from the outer layer of coal and (b) from a depth of 4 feet below the surface of the stack.

Sample (a) gave an evaporative power of 10.89 pounds, showing a loss due to weathering of 13 per cent. Sample (b) gave an evaporative power of 12.27 pounds, equal to a loss of 2.3 per cent.

When fresh wrought, the above coal contained 35 per cent. hydrocarbons.

Sample (c), Indian coal, consisted of a mixture of slack and nuts; thickness of sample during exposure was from 5 to 6 inches. The sample was subject to the weather conditions usually prevailing in Bengal from September to November.

With an exposure of fifty-six days, the loss due to weathering amounted to 6.6 per cent.

Sample (d), Indian coal.—The sample was powdered and passed through a No. 60 sieve, after which it was stored in a dry room. The powdered coal was left open to the atmosphere of the room. The loss from an exposure of fifty-six days equaled 7.5 per cent.

Sample (e), English coal.—The sample was in the form of small nuts; the coal was of a very tender nature, having been taken from near the outcrop of the seam.

When fresh wrought the coal had an evaporative power of 14.99 pounds; but after an exposure of eighteen weeks and four days the evaporative power was only 10.9 pounds, showing a heavy loss of 26 per cent.

The summary of the Illinois University experiments (*vide* Bulletin No. 33) was as follows:

(a) Submerged coal does not lose appreciably in heat value.

(b) Outdoor exposure results in a loss of heating value varying from 2 to 10 per cent.

(c) In most cases the losses in storage appear to be practically com-

plete at the end of five months. From the seventh to the ninth month the loss is inappreciable.

A locomotive engineer to one of the large railways in England stated, in 1902, that, judging from his personal experience and observation, the loss of stacked coal in steam-raising power is about 10 per cent.

The data here given is far from being conclusive; yet one fact is clearly demonstrated, namely, most coals, when exposed to the weather, or during storage, lose a considerable portion of their heating power.

The best method of protection appears to be that of submerging the coal in water.

Current Topics

RECENT trials of flying machines, both in Europe and in the United States, appear to have given the impression that such devices are still in a rather uncertain condition, and that flights can be attempted only under the most favourable conditions, when there is little or no wind, and when everything is quiet and calm.

Such a view is largely due to the fact that the development of the aeroplane is being conducted largely under the guidance of men who partake far more of the scientific cast of mind than by those of a sporting disposition, a condition of affairs which is most encouraging. Mr. Wilbur Wright, who, probably more than any other man, understands the situation, is wholly lacking in the sporting instinct, for which we are profoundly grateful. The idea that the man who, from genius and experience, is probably most highly qualified to advance the science of aviation, should risk his life in order that a waiting crowd of gaping spectators should not be disappointed, is a most unscientific and undesirable thing. Such people might well be directed to the most convenient circus, and be permitted to regale their vision with the antics of the tight-rope performers. The whole idea of aerial flights at the present time is one of scientific investigation—intended to advance the development of the apparatus and render it in time available for general, military and commercial purposes. The sportsman would have it enter the lists with the race-horse and the speeding automobile and become the toy of the amateur, at the risk of the lives of the men by whom its existence has been made possible.

The present condition of mechanical flight is one which demands the utmost caution and the exercise of the most highly-trained judgment. A Bleriot may cross the Channel at the first trial, while a Latham fails at both efforts, a result which shows the extent to which the element of chance and audacity governs the result. The Wright brothers continue their cautious and scientific experiments, and each flight adds something to the sum of human knowledge upon the subject, and brings the world one step nearer permanent success. The same is true of the patient efforts of Count Zeppelin with the development of the dirigible, and of the work of Julliot and the Lebaudy brothers in the same field. The opportunity of the sportsman will come later, and it will only retard progress to confound it with the methodical and deliberate investigations, and the cautious operations of the engineer and scientific investigator.

MR. W. H. WILSON'S paper on "Electrical Operation of Textile Fabrics," which was presented at a recent meeting of the Institution of Mechanical Engineers, was a more than ordinarily temperate statement of the case than is usually offered. There is a deal to be said for electrical driving, but no very serious economy is possible, though with old buildings driven by old, slow engines, it need surprise no one if a change to electrical driving gave excellent results. It is unfortunate that enthusiasts are apt to claim for new mills results that are obtained in comparing old mills when driven by old engines and then changed to electrical driving.

Nor would any engineer deny that the scattered paper mills, the bleach works, or print works are fit and proper cases for electrical driving.

It is estimated by the author that mechanical driving is better below 80,000 spindles: equal between 80,000 and 100,000 spindles and inferior to electrical driving for sizes above 100,000 spindles. But this refers to electricity generated by the factory itself. A Lancashire mill can produce power for 0.2 penny for indicated horse-power hour, the author admits. He says that fairly large mills will pay double this price per net unit, or 33 per cent. more than the above price, which means 0.3d. per unit, but even at 0.4d. we doubt the ability of some power stations to deliver to such a price. We quite agree with the author that to replace a line-shaft belt pulley by an electric motor, and call this electric driving, is hardly the thing. Some electricians would like to see a little synchronous motor on every spinning spindle. So would we, but we cannot hope to get to see this.

TWO new radio-active elements are described in *La Metallurgie*. The first is Nipponium (NP), found by the Japanese chemist Ogawa. This is a hitherto unknown element occurring in Thorianite, remite and molybdenite. It has an atomic weight of about 100 and an equivalent weight of 50. It has been named Nipponium in honour of the country of its discovery by Sir William Ramsay, and appears to fill the vacancy between Molybdenum and Ruthenium in the periodic scheme. It is a nearly white hydro-oxyde, which, heated to 100 degrees C., becomes nearly black. Its oxyde becomes brown afterwards and is insoluble in acids; its chloride volutilises with difficulty, is soluble in water and becomes a pale green liquid. Its spectrum is characterized by a green line in the wave length 4882 AE.

The other is Ionium, first presented by Bolwood; it is precipitated by means of certain defined chemical reactions from carnotite and other metals which contain uranium. It resembles thorite, inasmuch as it cannot be extracted by the ordinary reactive chemical processes. It has probably the same atomic weight as thorium. Its radio-activity is 1,000 times that of uranium, and it is at the ratio of 1-0.76 compared with that of radium. It produces X-rays and probably B-rays. Boltwood considers Ionium a decomposition of uranium and places it between it and radium.

THE safety to be obtained by periodical inspection of steam boilers by skilled men may be taken as conclusive proof that boilers do not explode from mysterious causes. The Manchester Steam Association give a guarantee of all boilers they consider safe, and those boilers have never exploded. Yet the guarantee is not withheld very strictly—not harshly, at any rate—and only for reasons which are sound and good. From time to time some writer brings forward the doctrine of mystery, and we are treated to dissertations on spheroidal conditions and shock. But it is strange that spheroidal conditions should fight so shy of inspected boilers. There are boiler owners who appear to insure their boilers so as to escape responsibility, and they will go begging from company to company in order to find the

one that will take the biggest risk and grant a policy to doubtful boilers. A boiler may be good, yet may have some danger points in its fittings. These are provocative of accident, yet are apt to be lightly regarded by owners. Yet plenty of explosions of strong boilers have taken place from one cause or another, not connected in any way with the fitness of the boiler itself to stand its designed pressure.

Inspection of itself may not effect much. It is the indirect effect on the attendance that counts for constant care. And so gradually there has been built up a high level of maintenance and care. Faults of all kinds have been traced back to causes, and the causes eliminated in construction. Construction has been brought to a higher level, and, under voluntary inspection, the land boilers of Great Britain have reached a higher level of safety than the government-inspected boilers of Germany, the police-inspected boilers of the United States, and even of the marine boilers inspected by the British Board of Trade.

THE kinetic theory of gases is an extremely useful aid in the forming of mental conceptions as to what occurs in relation to gaseous movement and pressure. According to Clark-Maxwell the pressure of a gas in an enclosed vessel is due to a bombardment of the containing envelope by the gaseous molecules. But the theory is now stated by the *Engineer* to be untenable, on the ground that it cannot be true unless the molecules are perfectly elastic, and the walls are either perfectly rigid or perfectly elastic. If not, the gas will lose energy. We confess we fail to follow the argument. The walls of the containing vessel are placed in a state of stress by the pressure within, and the molecules of the walls are then in a state of stress energy. The molecules do actually part with energy in the process of distending the walls against their own resistance or the height of the atmosphere. The loss is small, except in the case of an elastic balloon, which distends in volume considerably and allows much atmosphere to be thrust aside. If it be allowed that the gaseous molecules do lose energy to the walls, then must it be admitted that they will be cooled in the process. But they cannot cool below the surrounding temperature, and thus it follows that they get back all the heat they lose. The kinetic theory is as useful as is the atomic theory. Neither of these may be representative of fact any more than the theory of the ether, of ions, of electrons or other of the late scientific jargons. But we do not think the argument of our contemporary will avail to rout the kinetic theory. After all, these various theories do but serve to help our immatured intellects and to push back the boundary lines of illimitable spaces further into infinity. None of them absolutely solves the riddle. There is still a door to which we find no key.

THERE is no method of conveyance so cheap and easy as that of sliding down hill. In the laying out of works of certain manufactures, a hillside site is often of great assistance towards this desirable end, even if it is first found necessary to elevate material to the top point in order that it may afterwards gravitate to lower elevations. The rough process of elevation in one operation can be done on raw material more cheaply than the elevation in stages of finished material, which must afterwards descend in one step, perhaps with the risk of destruction. This question of conveyance should always be most carefully studied in the laying out of a works, for raw material will usually suffer less damage than finished material by rough handling. Certain rough conveyors, however, have been brought to perfection for coal handling and conveying, which do their work with a minimum of disturbance, and these are equally useful for other materials which do not require

careful handling. Coal is a rough material, yet it is more damageable than wheat, which is a fine product. Often the necessity arises for conveying something horizontally. There is no room to employ gravity in one step by raising the material and then letting it descend by a slope across the horizontal distance to be traversed. The outcome of this is the rotary small diameter tubular conveyor, in which are fitted a number of inclined lifting blades. These lift the material, which slides down the short inclined blades, and material is thus shifted forward an inch or so every time it slides. Unlike the worm conveyor, the whole of the material moves forward. In a worm conveyor, some of it remains behind. The tube conveyor may also be used as a mixer of two or more materials and will produce a very homogeneous blend. It can also be used as a sieve or separator, especially in the case of seeds of different sorts and sizes.

THE annual report of the chief engineer of the Manchester Steam Users' Association for 1908 has been issued, and contains more about the very important subject of water-hammer in pipes. Mr. Stromeyer has for some time recognized the importance of steam-pipe design, and has given very special and careful study to water-hammer. In the course of his studies he has been led to see into the subject much more deeply than it has been customary to search, and he has pointed out various little suspected ways in which dangerous water-hammer may be set up. Some of the failures and the arrangements which caused failure are illustrated, and a very strange collection they make of failures of drain pipes, bad design and careless work.

One thing that is very obvious is the danger of the ordinary mushroom valve. The gate valve is safe. Another thing is the importance of placing the boiler-stop valve at the highest point and sloping the steam pipe from the valve to the engine separator.

Needless to point out the danger of lengths of pipe lying lower than pipes beyond. Dips of this sort are particularly dangerous. It is well that steam pipes should be better looked into. The last few years of power-station work has fortunately seen the last, or almost the last, of the foolish ring main so dear to a section of electrical men. The ring main was supposed to be an entire preventive of stoppage, and the ring main faddists put valves at every conceivable point; but some of them exercised very little thought in what they did, for we have seen the hand wheels of the valves of a so-called ring main situated on a gallery built just over the main, so that access to a valve was likely to be allowed only through an impossible risk of scalding steam. Water-hammer may be caused by any small plugs of water driven by steam pressure into vacuous ended pipes. A plug of water so driven will attain an enormous velocity, as may be readily calculated. A continuous pull of one pound on a mass of one pound will give an acceleration of 32 feet per second. Thus, in a 6-inch pipe a plug of water 1 foot in length weighs 12 pounds. Its area is, approximately, 28 square inches, and with a boiler pressure of 85 pounds gauge, or 100 pounds absolute, the acting pressure to push that plug into a vacuous end of its pipe is 2,800 pounds, or 233 times the weight of the water. The acceleration in a tenth of a second would be 3.2×233, or 745.6 feet, or over 7,000 feet per second by ordinary theory. But this velocity would be double the rate at which steam itself could travel, for there is a limit to the velocity of steam. Sufficient that a plug of water would very soon acquire the velocity of steam. Few pipes are so long as 745 feet. A length of 74 feet would be traversed in the hundredth part of a second, and this represents an enormous

capacity for dealing a blow where the resisting medium is inelastic. Reference is made to the very unsatisfactory nature of the official inquiries into explosions. We quite endorse Mr. Stromeyer's strictures, for Board of Trade inquiries appear to us to be blind muddlings of a pack of legal gentlemen who don't know a boiler from a water-hammer. It is high time that we had a change in these matters, and that such inquiries were conducted by engineers.

SOME time ago there was discussed in this magazine the subject of artificial congestion centres in cities, and it was pointed out that the modern system of constructing huge railway terminals produced difficulties which were wholly avoidable had sounder reasoning prevailed.

A notable example of such artificial congestion is already appearing in connection with the new passenger terminal of the Pennsylvania Railroad, now nearing completion in the heart of New York City.

The railway is to enter the city through a pair of tunnels beneath the Hudson river, these tunnels opening into a large yard and into the space beneath the great station, the space having been practically quarried out of the rock upon which the city is built. The tunnels then pass on beneath the city, crossing both it and the East river, and communicating with the railway lines beyond on Long Island.

Passengers who wish to travel on these important lines will, therefore, be compelled to gather at the point where the new station is situated, while trains for all parts of the country will take their passengers in the limited space thus hollowed out in an already crowded district, and then await their turn to escape in either direction through either one of two tubes.

Already it is announced that plans are being made for the clearing away of all possible obstructions on the streets and places leading to the new station, and the authorities evidently realize that they will have conditions to meet at the new location which will rival and possibly exceed those already notorious at the entrance to the Brooklyn Bridge.

The colossal blunder which has thus been made in the erection of the new station is already becoming apparent. The extent of the mistake is emphasized by the fact that the extension of the railway system into the city afforded such a remarkable opportunity for the distribution of passenger traffic instead of the creation of a new centre of congestion. The two tubes cut across New York, passing beneath the most active and desirable part of the city, crossing all the main avenues which extend north and south throughout its length, and thus rendering it possible to have provided six or eight underground stations of moderate size, similar to the larger stations of the present subway, and permitting passengers to go to the point nearest to their own situation, and, on arriving, to descend at the avenue which would lead most directly to their ultimate destination.

True, there would have been no imposing station building, no great waiting rooms, no train yard, none of the accessories so closely associated with the ordinary railway terminal. All these things would have been relegated to some unconspicuous place without the city, or would have been rendered unnecessary. The lines of waiting cabs would be absent, and so would the long walks for the passengers along the crowded platforms. The railroad would have lost much of the publicity gained by the presence of the station, but it would have gained immensely in ease of handling its passengers, while the passengers themselves, usually the last to be considered in such plans, would have saved in time, in temper, in comfort, and in actual continuity of transport between their own terminal points.

As it is, the new station will be the latest example of the "bottle-neck" difficulty which is already the bane of railway terminal operation, and that, too, when all the local conditions gave the very best opportunity of preventing a congestion for which plans are now being made, even before it has arrived.

ACCORDING to Mr. Addenbrooke in his recent Cantor Lecture, a colliery consumes about six per cent. of its own coal output in operating expenses. If, he says, such collieries were electrically operated, this percentage would be reduced to two. We presume that very much the same result might be achieved if a colliery were equipped with steam plant of the quality considered necessary in good factory work, and with electrical transmission for the underground work. Too often the steam plant of a colliery is of the lowest order. The boilers are roughly set, and exposed to all the winds that blow. There is not always a roof to give shelter from the rain, and there is a general air of dirt and dishevelment which cannot be accepted as a necessary concomitant of colliery working. All this ought not to be. Profits are being carelessly burned up as though it cost nothing to burn any amount of coal of one's own getting.

JOSEPH HARRISON, JR.

A BIOGRAPHICAL SKETCH

IN view of the interest and importance at the present time of everything which relates to the development of railroading, it is well to remember what has been done in America to lay the foundations of the locomotive industry, and, therefore, we feel that it is desirable to recall the extent to which the design of the modern locomotive is indebted to the work of Joseph Harrison, Jr., although it is now more than thirty years since he passed away.

Joseph Harrison, Jr., was born in Philadelphia in 1810, and acquired his mechanical training in the old-fashioned way, for he was indentured as an apprentice in the art of machine making at the age of fifteen years, these indentures being with F. D. Sanno, who had a small machine shop in Philadelphia, and with James Flint, who owned a more pretentious establishment. During his apprenticeship he attended night schools and studied assiduously, and after the expiration of his apprenticeship he worked in various shops in Philadelphia, the most important one being that of Philip Garrett.

The famous run of George Stephenson's "Rocket" was made at Rainhill, England, in 1829, and it did not take long for the locomotive-building industry to reach America. By 1833 Col. Long and William Norris were beginning the manufacture of locomotives in a small way in Philadelphia, and young Harrison entered their shop, which at that time employed only thirty men.

In 1835 Mr. Harrison entered the employ of Messrs. Garrett & Eastwick, locomotive builders, and became a member of the firm of Garrett, Eastwick & Co. in 1837.

Up to this time all the locomotives built either in Europe or America had but a single pair of driving wheels, and the tractive effort was necessarily very limited. Attempts had been made to use more than one pair of driving wheels, but the difficulty of distributing the load upon the drivers had caused such machines to be unsuccessful. In 1837 Mr. Harrison undertook to design a locomotive with four driving wheels, using a bogie truck in front, and making the first use of the equalizing lever to insure the equal division of the load upon the two axles. The "Hercules," built in 1837, a replica of which was included in the historical railway exhibit made for the Chicago Exposition in 1893, was thus the first successful application of the equalizing lever to the locomotive engine, a feature which is at the present time the means by which the "decapod" and other heavy types of modern locomotives are possible. This invention was patented in 1838, and in 1839 Mr. Garrett retired, and the firm of Eastwick & Harrison continued the construction of locomotive engines of the new design.

In 1840 the remarkable performance of one of the new locomotives, on the Reading Railroad, attracted the attention of a commission of engineers sent from Russia by the Emperor Nicholas I., the object of the visit of the Russian engineers being to secure the most desirable design for the rolling stock of the new railway between St. Petersburg and Moscow, the road-bed of which was

then about completed under the supervision of Major George W. Whistler, U. S. A., who acted as consulting civil engineer for the railway. The result of this incident was the visit of Mr. Harrison to St. Petersburg and the closing of an important contract by him with the Russian Government for the entire equipment of the road with locomotives, freight and passenger cars, etc., as well as the equipment and organization of complete repair and construction shops at Alexandroffsky, near St. Petersburg. This contract, made in 1843, was followed by a second one, extending from 1850 to 1856, and under both of these Mr. Harrison acquired a large fortune. In addition to these railway contracts, Mr. Harrison undertook, and successfully completed, the iron arch Bridge of the Annunciation across the river Neva, this being the first permanent structure by which the two portions of the city were united, and replacing the fragile pontoon bridges which had formerly been used. For his successful and satisfactory completion of these various undertakings Mr. Harrison was decorated by Nicholas I. with the Order of St. Ann, besides receiving numerous other tokens of the friendship and esteem of the Emperor. The second railway contract was ultimately extended to 1862, and in this portion of the work, including the operation of the St. Petersburg & Moscow Railway, there were associated with Mr. Harrison Messrs. Thomas Winans and William Winans, of Baltimore.

Upon his departure from the United States for Russia Mr. Harrison disposed of his American patent for the equalizing lever to Mr. M. W. Baldwin, of Philadelphia, who employed it on all his succeeding locomotives, and thus introduced it into the development of locomotive engineering in America. The engines designed and built by Mr. Harrison in Russia were wholly different in construction from those of the same period in other parts of Europe, resembling very closely those known as the American type, using two or three driving axles and having a swivel truck in front.

In addition to his part in the development of locomotive engineering, Mr. Harrison did much to advance the construction of sectional steam boilers, the multiple-sphere sectional safety boiler bearing his name, and formerly very extensively used, having been patented by him in 1859. The Harrison Boiler Works, founded by him in Philadelphia for the manufacture of this boiler, is now actively engaged in business, manufacturing a number of important and successful steam specialties.

After his return to the United States Mr. Harrison resided in Philadelphia until his death, in 1874, being one of its most eminent citizens, a patron of the fine arts, and interested and active in the welfare of his native city.

In addition to his decoration from the Russian Emperor, Mr. Harrison received the Rumford Medal for his efforts to secure safety in the generation of steam, and was also awarded medals at the London International Exhibition of 1862 by the Franklin Institute and other industrial organizations.

Photograph by Allan & Barker, Newark.

SPENCER MILLER

LIDGERWOOD MANUFACTURING COMPANY

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THE FRANKFORT AERONAUTICAL EXHIBITION

By J. O. Newman

In view of the present interest in all that pertains to aeronautical matters, the exhibition held at Frankfort must be considered as of immediate importance, and hence we believe that the accompanying review of the principal exhibits will be found acceptable, not only to those who are engaged in the perfection of flying machines, but also to all who realize the importance in the progress of an industry which is in a position not very greatly different to that which was held by the automobile question a little more than a decade ago.—THE EDITOR.

AN examination of the Aeronautical Exhibition at Frankfort reveals a decided advance in the position of the dirigible during the period which has elapsed since the publication of the article in the April issue of this magazine. Since that time the Zeppelin II. and III., representing the rigid type, have made their memorable long-distance flights, while the Parseval dirigible, representing the non-rigid type of airship construction, has done wonderfully good work, demonstrating that it is easy of control and that it can maintain its position at an altitude of 4,000 feet without difficulty. In view of the success of the Parseval machine, the following table of dimensions, representing balloons constructed by the Luftfahrzeug Gesellschaft, of Berlin, will be of interest, especially since these formed one of the principal attractions at the exhibition.

The dimensions, etc., all in the metric system, are given below.

The body of the Parseval balloon is of a peculiar shape, the front being rounded, followed by the cylindrical portion, which tapers to a point. The form has been adopted as being most favourable for speed and resistance, according to the trials with models which have been carried out at Göttingen by Professor Prandtl. The hull is made of double diagonal Egyptian cotton, with a coating of heavy Para rubber between. The main balloon is filled with hydrogen, and there are two interior ballonets, which can be kept filled with air to maintain the tension of the whole. These ballonets are situated, one in the forward part of the main balloon and one aft, and by filling one or the other with air the increased volume fore or aft changes the position of the balloon, and consequently its ascent or descent while in motion. Stability planes and rudder are attached to the balloon, while the propeller, motor, etc., are on the car. The rudder and stability planes are composed of bags on steel frames, rendered rigid by means of air pumped into them. The position of the propeller blades may be changed at will and its direction reversed. Various motors have been used with the Parseval balloons, including the N. A. G. motor of 100

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Capacity, Cubic Metres.	Length, Metres.	Greatest Diameter, Metres.	Greatest Width Including Stability Planes.	Total Height, Metres.	Cas Length.	Cas Height.	Cas Width.
Type A, 4,000	60	10.4	16.	20	6.	1.3	1.2
Type B, 6,600	70	12.3	17.	22	10.	2.0	1.4
Type C, 2,000	50	8.6	14.	18	8.5	0.8	1.1
Type D, 1,200	40	7.7	12.	16	5.	0.7	1.0
Type E, 3,200	60	9.4	15.	19	7.	1.3	1.2
Type F, 1,600	45	8.2	12.5	17	5.5	1.0	1.0

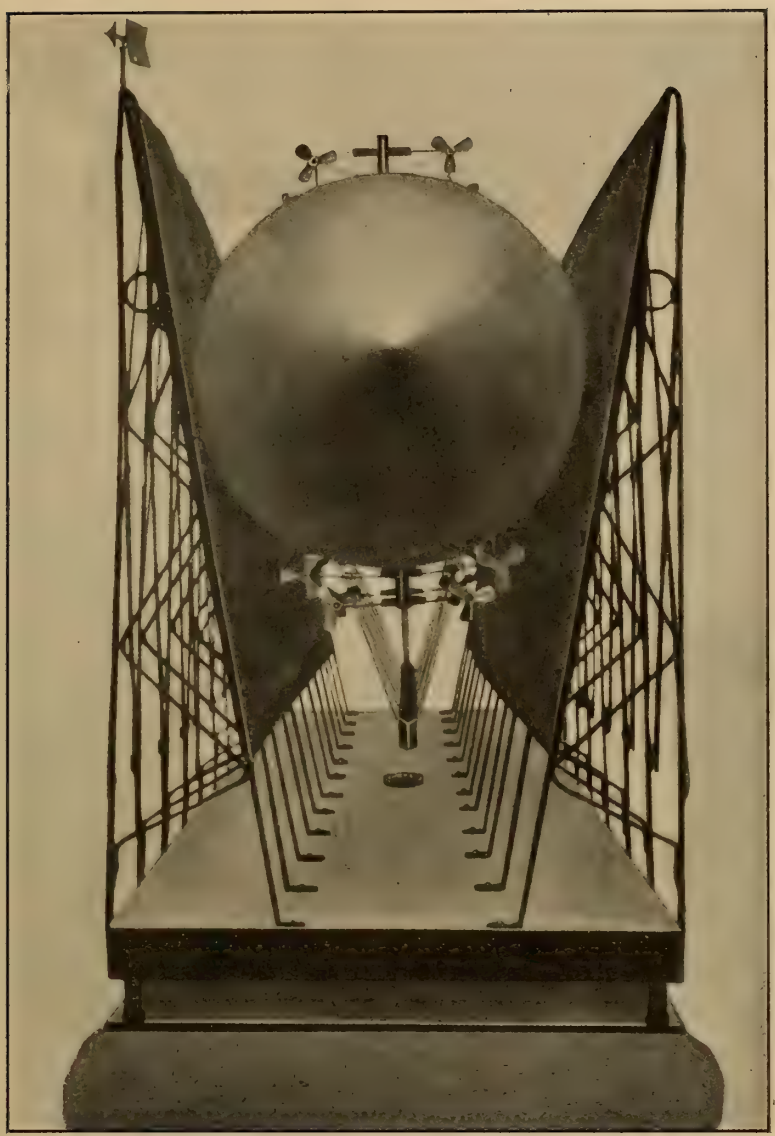
horse-power, the Daimler motor of 100 horse-power, and 50-horse-power motors built by the Eisenach Works, illustrated in this article.

Several aeroplanes were shown at the exhibition, some of them being of the most weird shape. Among these machines was a dynamic flying machine and glider by Ehrich Frowein, of Elberfeld, which, during demonstrations, showed good stability and ease in manœuvring.

An interesting machine, shown in the illustration, is the wing flyer by J. & R. Braun, of Brand, this being a working model. The wings and planes are operated by crooked levers placed on the car, some distance below the planes, this position giving a high degree of stability by keeping the centre of gravity low. So far as the mechanism is concerned, the whole apparatus is very simple, the use of a propeller being avoided by the peculiar movements of the wings and planes.

The wings move up and down, and may be turned about their axes either upward or downward for ascending or descending steering. The two planes also have an alternate movement, in accordance with the movement of the wings. It will thus be seen that the machine is designed according to quite different principles from those of the aeroplane, and, if successful, should be almost entirely independent of wind and weather, on account of the small opposition offered to head winds. The large resistance of the outspread wings and planes should prevent sud-

WING FLYER. J. & R. BRAUN, BRAND



OPEN AIRSHIP HALL. ALBERT WETZEL, STUTTGART

den or disastrous descent in the event of the stoppage of the motive power.

The development of aeronautics has resulted in the production of a new department in engineering—the construction of balloon halls. Some of these structures were erected within the grounds for the purpose of housing the dirigibles assembled for trial flights. One of these halls, erected by Arthur Müller, of Charlottenburg, was 70 metres long, 25 metres wide and 20 metres high, and was built for the Motor Luftschiff Studien Gesellschaft, of Berlin, for housing the Parseval balloons.

A number of other types of halls were shown by models, some intended for iron frames and some for wooden construction. A special design is so arranged as to be turned on rails to any desired position, according to the

direction of the wind. In the design of Otto Walberg, of Frankfort, four doors are provided, and the walls are made with slats, something like those of Venetian blinds, which, under heavy wind pressure, will open and relieve the wall of the strain. The Gutehoffnungshütte, of Oberhausen, shows a hall capable of housing two Zeppelins at a time, being circular in plan, 180 metres in diameter and 44 metres high in the centre, and having more than 20,000 square metres of space. Twelve large gates permit entrance from any direction, and the absence of any columns or obstructions renders the handling of the machines easy.

A practical manner of providing a shed which can be turned in any direction to meet the wind in starting, or to accommodate the homing balloon, is seen in the floating type, designed by Alb. Buss & Co., of Wylen. This is a model of the structure which floats on the Lake of Constance, near Friedrichshafen, the model being exhibited on a small raised pond at the exhibition. The weight of the car is taken off the balloon at once by the buoyancy of the water, while the provision of three galleries at various heights affords ready access to all parts of the machine for testing, inspection, or repairs. A novel type of house, open at the top to permit the balloon to descend directly into it without requiring a large, open space for manœuvring, is shown in the design of Albert Wetzel, of Stuttgart. The walls are of sheet metal, inclined together to support the balloon, and the airship is kept on the platform by suction, the rings on the bottom of the car being in communication with a vacuum space within the car.

MOTOR BALLOON GUN. FRIEDRICH KRUPP, A. G., ESSEN A./RUHR

From a military point of view, the new guns, especially constructed for attacking balloons, were most interesting. It has been demonstrated that ordinary infantry fire is almost entirely useless for this purpose, since the small holes do not cut clean through the fabric, and the threads and loose material, aided by the

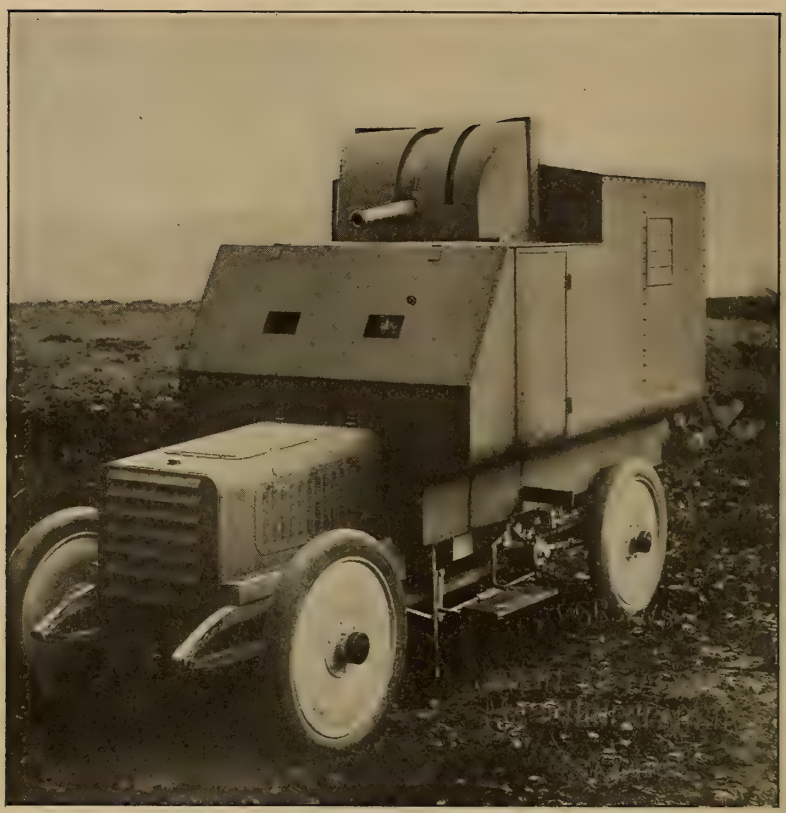
pressure of the gas, close them up. Trials in Germany showed that 30,000 bullet holes, put into a balloon at close range, failed to bring it down. The result has been the production of special forms of artillery to protect the infantry from the attacks of sharpshooters in balloons, or for the destruction of aerial reconnoitring parties.

In the illustrations are shown a Krupp field gun of 6.5 centimetres bore, arranged to be tilted up to an angle of 75 degrees; also, a similar this being on the Ehrhardt system, represented by a 5-centimetre size, although this design is also made with bores of 7.5 and 10.5 centimetres. The gun is mounted on a centre pivot, the position being controlled by a small hand wheel, the sighting and firing being performed by one man. It can be elevated to an angle of 70 degrees, or depressed 5 degrees, and has a horizontal field of 60 degrees. These guns are mounted on motor cars, the one shown being of 50-60 horse-

KRUPP FIELD GUN FOR BALLOON ATTACK

gun of 7.5 centimetres bore, with an angle of 70 degrees, the latter mounted on a 65 horse-power motor car capable of a speed of 50 kilometres per hour. Both guns have a very long and high trajectory, and are fitted with automatic recoil, and the projectiles are provided with smoke rockets for the purpose of indicating the path of the discharge and aiding in rectifying the aim. A particularly fine example of gun is shown by the Rheinische Metallwaren und Maschinenfabrik, of Düsseldorf, power, capable of making a speed of 45 kilometres per hour and overcoming grades of 22 per cent., even on bad roads. During the firing of the gun four struts are let down to steady the car. The gun has a muzzle energy of 24.8 m. t., and the greatest distance to which the projectile has been carried is 7.800 metres, this being attained with an angle of fire of 43 degrees. At its maximum elevation the gun carries up to 3,800 metres.

The automobile on which these



BALLOON GUN MOUNTED ON FULLY PROTECTED CAR. RHEINISCHE METALLWAREN- UND MASCHINENFABRIK, DUSSELDORF

guns are carried is armoured, as shown in the photographs, the whole, including the wheels, being protected by nickel-steel plates 3 millimetres thick. The gun-shield proper, which also is provided with holes for riflemen, is arranged to rotate, and the ammunition is carried in a box under the back seat. The total weight, including car, gun, ammunition and five men, is 3,200 kilogrammes, or about 3¼ tons.

In this connection mention may be made of the projectiles made by the same firm, which combine the properties of the shrapnel and common shell. By suitable adjustment of the fuse the front, or shell part, may be caused to explode at the same time as the shrapnel, or, the shrapnel part having exploded and thrown a shower of grape shot over the target, the head or shell is made to continue its flight and explode when reaching the target.

A number of motors adapted for airships and aeroplanes were exhibited, some of these being of well-known types and others of new design. Among these we may mention the four-cylinder motor made by Palous & Beuse, of Berlin, this being very simple in construction and weighing from 1.24 to 2 kilogrammes per horse-power, in sizes from 20 to 100 horse-power. Other motors include the Taunus, a four-cylinder machine, the cylinders being 140 mm. bore and 129.8 stroke, giving about 60 horse-power at 1,200 revolutions; the Adler six-cylinder motor, 115 mm. bore, 135 mm. stroke, 100 horse-power; and the motors of 20 to 40 horse-power made by George Jungbluth, of Frankfort-Bockenheim.

A monoplane of special design, in-

cluding a new type of motor, was to be shown by Handley & Page, Ltd., of Creekmouth, Essex, all parts to be British-built; but the only portion exhibited at the time of the visit of the writer to the exhibition was the propeller, made from a single piece of wood.

A small balloon made by the Continental Caoutchouc & Gutta Percha Company, of Hannover, and intended for the transport of instruments, is worthy of mention. This company is the manufacturer of the fabric described above as used in the construction of the Parseval balloons, and has furnished much of that employed in other airships and aeroplanes; but in the case of the small balloon now under consideration the gas bag is made entirely of thin sheets of pure Para rubber, cut from the block.

Methods of generating hydrogen have been greatly improved since the old sulphuric-acid days. The installation owned by the military authorities at Cologne, and used for filling the Zeppelin dirigibles, is of the latest type, built by the Maschinenfabrik Sürth, near Cologne.

There is exhibited at Frankfort a duplicate of the compressor used in this installation, where there are two separate sets, each including a tandem steam engine with Sürth superheaters, coupled directly to a hydrogen compressor having a capacity of 125 cubic metres per hour. The compressor operates in three stages, sextupling the pressure each time, as follows: 1:6, 6:36, 36:196 atmospheres. The three compressing cylinders lie in one line, forming practically one piece, as shown in the illustrations, and with this machine it is practicable to charge steel bottles of 36 litres capacity with hydrogen compressed from 150 to 175 atmospheres.

A model hydrogen plant is exhibited by the Elektrizitäts-Aktien-Gesellschaft, formerly Schuckert &

BALLOON GUN MOUNTED ON A SEMI-PROTECTED CAR. RHEINISCHE METALLWAREN- UND MASCHINENFABRIK, DUSSELDORF

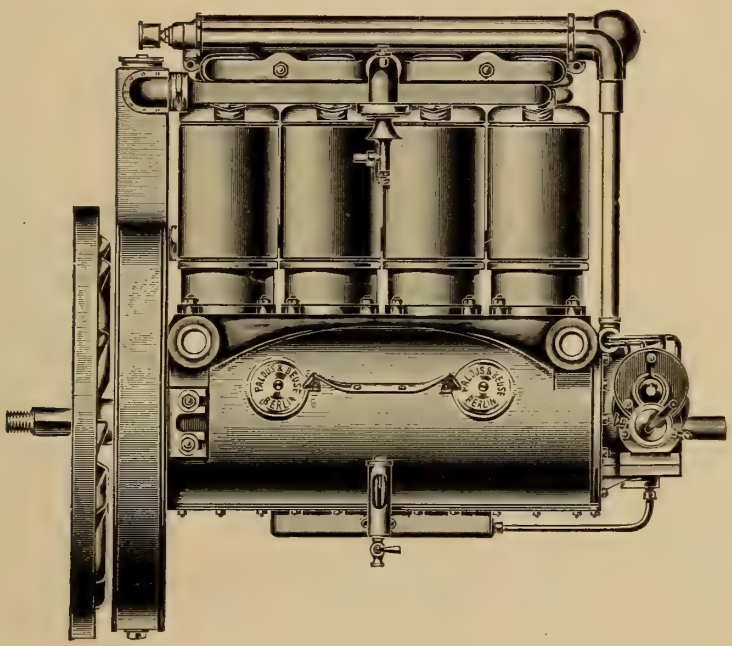
BALLOON GUN IN HORIZONTAL POSITION. RHEINISCHE METALLWAREN- UND MASCHINEN-FABRIK, DUSSELDORF

Co., of Nuremberg, this being intended for the manufacture of hydrogen by the electrolytic decomposition of water. A high-tension, three-phase alternating current is produced by a small generating station, this current being transformed into a continuous one by a motor-generator and delivered into a battery room containing thirty-six electrolysing elements, capable of producing about 50 cubic metres of hydrogen and 25 cubic metres of oxygen per hour. The gases are drawn off through pipes and delivered to washers, in which a spray of water removes mechanically entrained impurities, after which the hydrogen is stored in holders under a water pressure of 90 mm. for delivery directly into balloons or to compressors for filling bottles. Some installations made by this firm have a capacity of 1,000 cubic metres per hour; but as large volumes of hydrogen are required at short notice for filling balloons, it has been found desirable to use gas holders to keep the plant within reasonable dimensions.

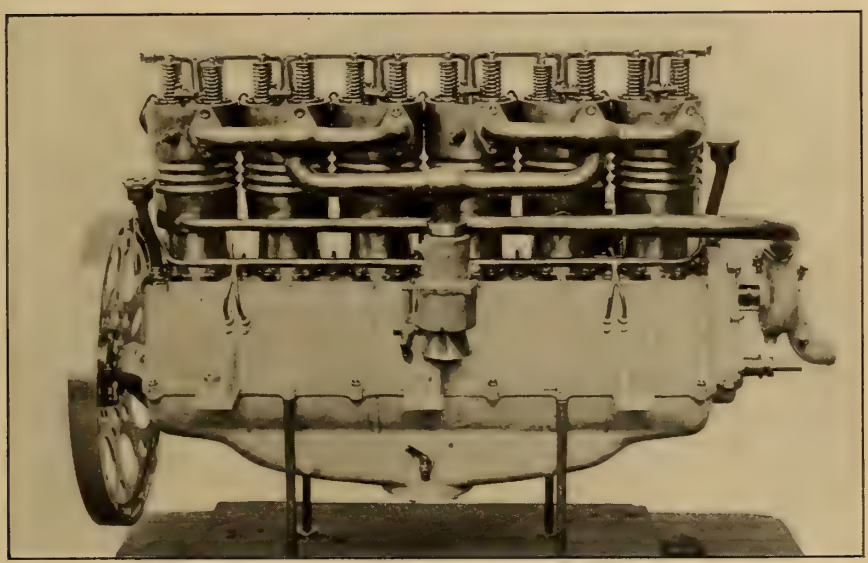
Portable hydrogen plants are shown at the exhibition, and also motor wagons with trailers capable of carrying eighty bottles of hydrogen, the total weight of car and load being about 6 tons.

Besides its use for filling balloons there is also a demand for hydrogen for the autogenous welding of metals, such apparatus being shown by the Chemische Fabrik Griesheim Elektron, as well as the appliances

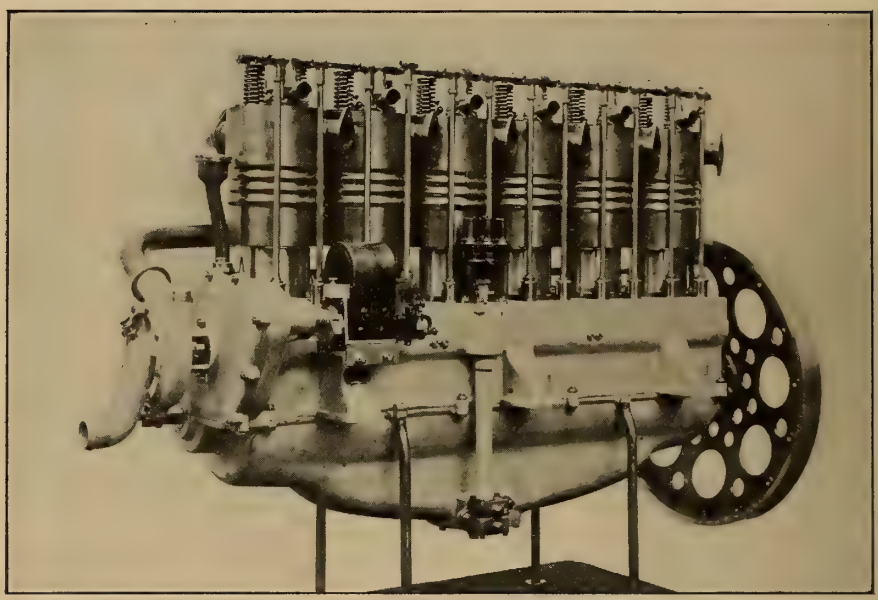
EHRHARDT BALLOON GUN IN HIGHEST POSITION



FOUR-CYLINDER MOTOR FOR AIRSHIP. PALOUS & BEUSE, BERLIN



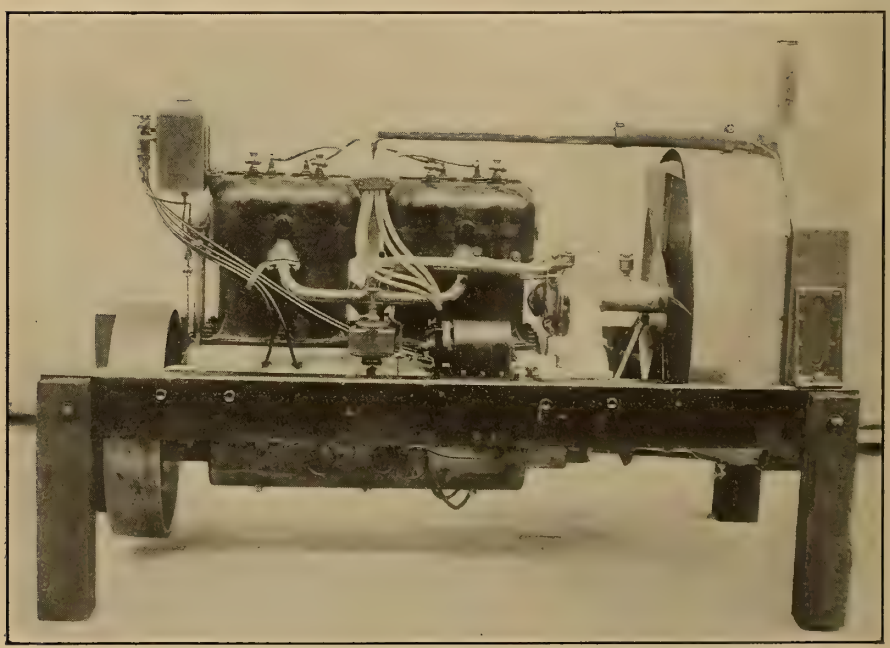
SIX-CYLINDER AIRSHIP MOTOR. ADLERWERKE, VORMALS HEINRICH KLEYER, FRANKFORT A./M.



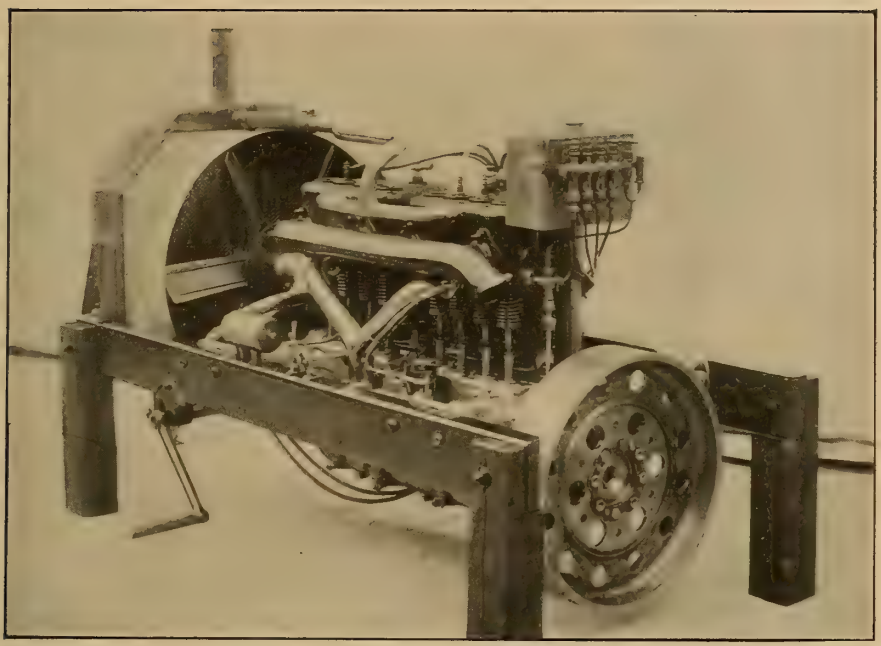
SIX-CYLINDER MOTOR FOR AIRSHIPS. ADLERWERKE, VORMALS HEINRICH KLEYER, FRANKFORT A./M.

for cutting girders and other metallic pieces by means of the blow-pipe flame.

The same firm is also bringing out a new alloy called "Elektron," a name which must necessarily cause much confusion, since it has already been used to denote quite a different thing. The basis of this alloy is magnesium, with its low specific

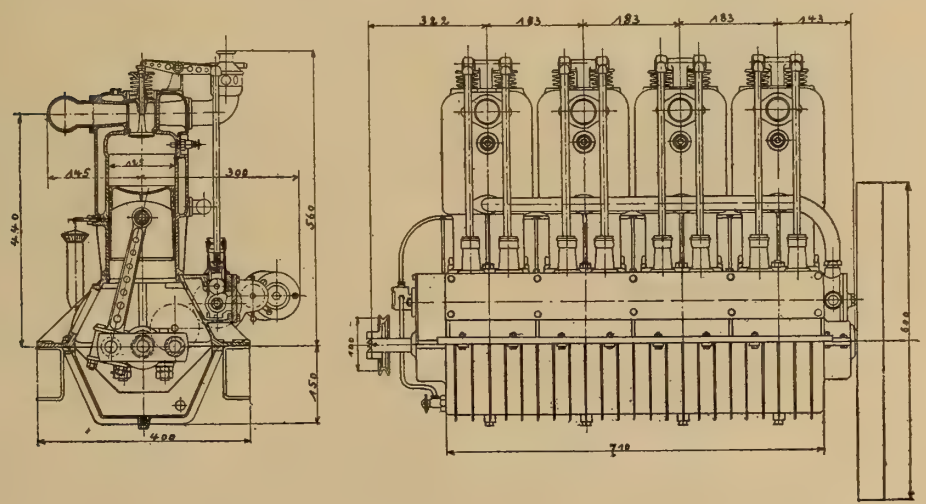


MOTOR USED IN PARSEVAL DIRIGIBLES. FAHRZEUGFABRIK EISENACH, EISENACH

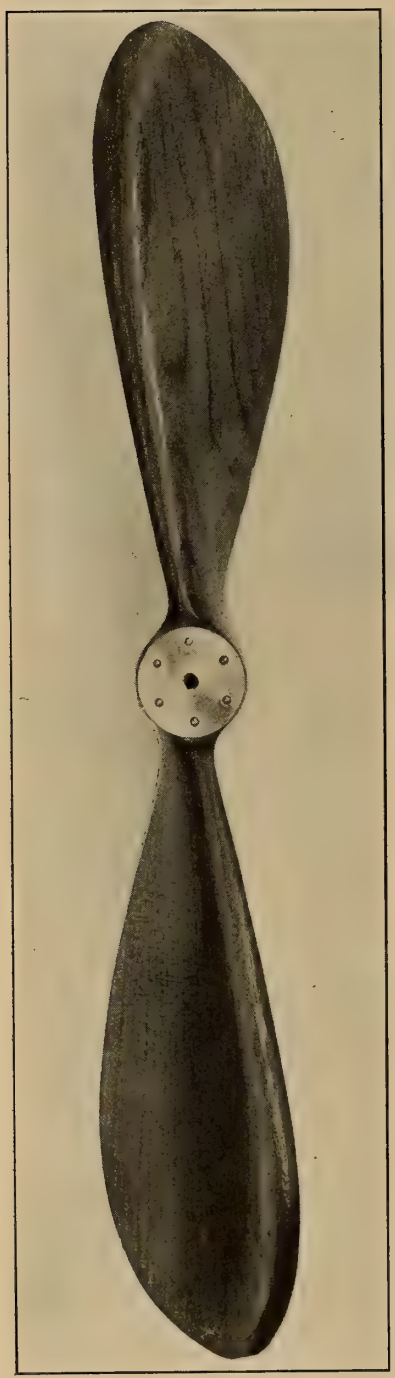


MOTOR USED IN PARSEVAL DIRIGIBLES. FAHRZEUGFABRIK EISENACH, EISENACH

gravity of 1.75, as opposed to that of 2.57 for aluminum, which has tempted manufacturers to undertake a number of experiments, the result of which is a material with a specific gravity of less than 2.2. The other constituents of the new material have not yet been made public; but it is claimed to be easily workable, and to combine strength and toughness with elasticity. As the specific gravity of aluminum alloys is about 3.00, the advantages of this new material for the construction of machinery



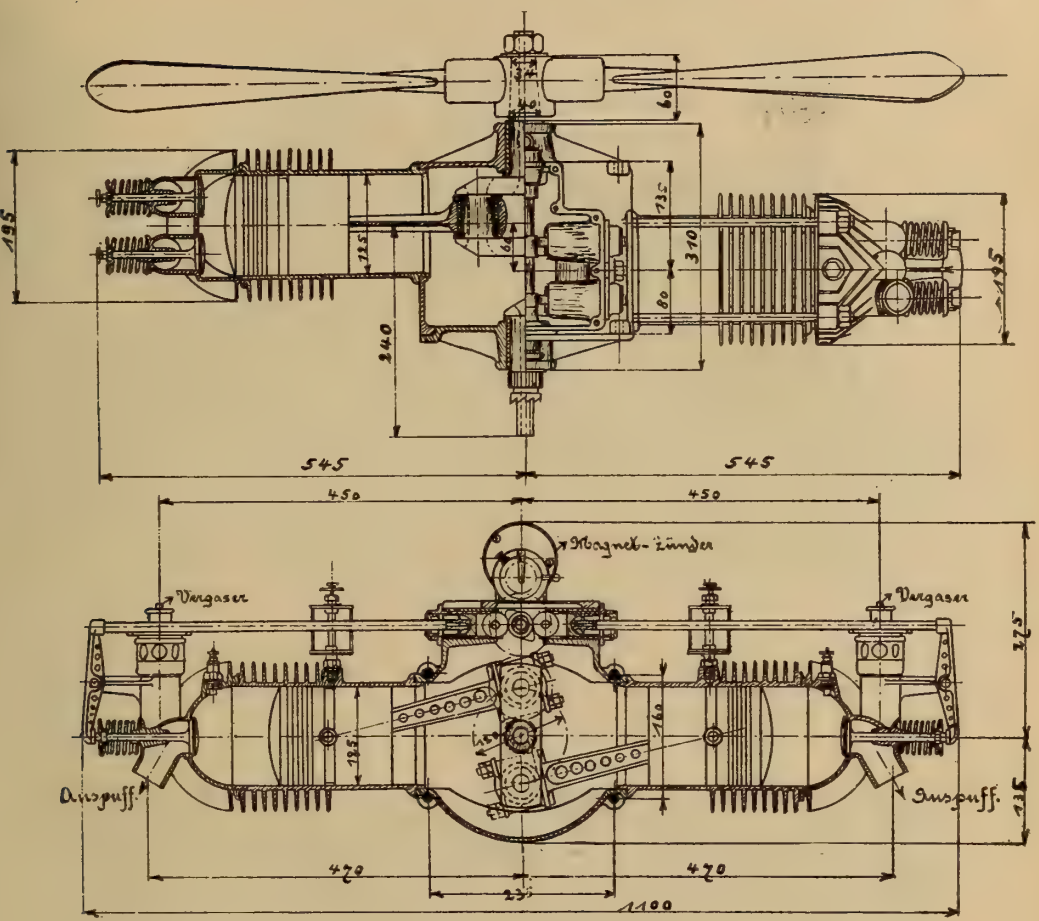
FOUR-CYLINDER AIRSHIP MOTOR, 40-50 HORSE-POWER. GEORGE JUNGBLUTH, FRANKFORT-BOCKENHEIM



ONE-PIECE WOODEN PROPELLER. HANDLEY & PAGE, LTD., CREEKMOUTH, ESSEX

and parts of aeronautical apparatus are obvious. It yet remains to be seen if the oxidation of the magnesium in contact with the air will have a detrimental effect, but the manufacturers believe that such will not be the case. Tests of the new material show a tensile strength of 18 kilogrammes per square millimetre (about 26,000 pounds per square inch) and an elongation of 5 per cent. By a process of compressing, drawing and rolling it is claimed that both the tensile strength and elasticity of the material may be increased, so that the tensile resistance reaches 35 kilogrammes per square millimetre (about 40,000 pounds per square inch) and the elongation reaches 18 per cent., without material increase in specific gravity. If a motor which now weighs 200 kilogrammes can be reduced to 125 kilogrammes, and if the aluminum frame of a Zeppelin can be reduced in a corresponding proportion, it follows that either the amount of fuel carried may be greatly increased, thus enabling the balloon to make longer voyages, or a greater number of passengers may be carried.

Aluminum, which is coming more and more into prominence in the manufacture of airships and aeroplanes, is well represented at the exhibition. The Metalwalzwerke, of Frankfort, shows some very fine seamless tubes of aluminum. The A. G. Autogene Aluminum Schweissung, of Zurich, is especially well represented by exhibits of gas bottles, pipes and other receptacles, some with walls of 3 mm. in thickness, capable of resisting a pressure of three atmospheres. The largest aluminum exhibit is that of the Sud-Deutsche Kable Werke, Heddernheimer Kupferwerke, Frankfort. Iron and aluminum pipes, 18 feet long and 3 feet in diameter, are shown, also heavy aluminum sheets up to 1,000 kilogrammes in weight, also seamless tubes of all dimensions down to 2 mm. diameter, and a peculiar kind of bronze called Aeterna metal,

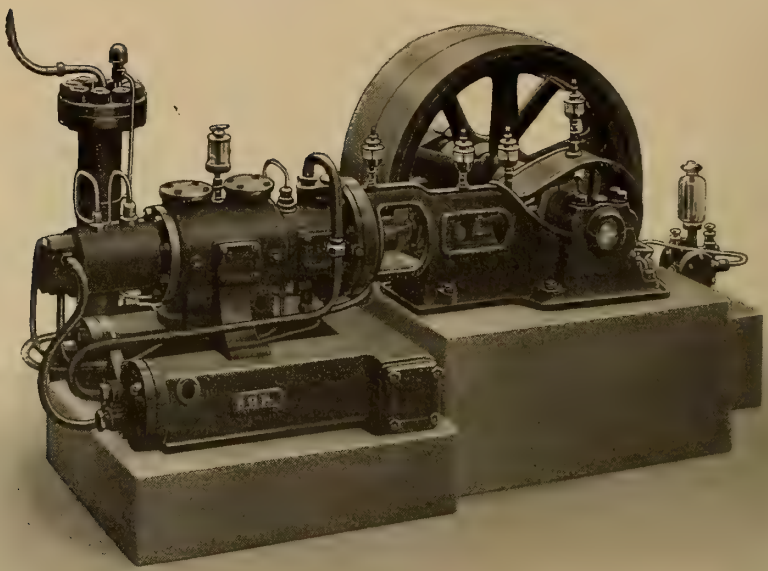


FOUR-CYLINDER AIRSHIP MOTOR, 20 HORSE-POWER. GEORGE JUNGBLUT, FRANKFORT-BOCKENHEIM

in the form of seamless tubes and castings. This metal is claimed to have a tensile strength of 40 to 55 kilogrammes per square millimetre (59,000 to 78,000 pounds per square inch), with elongations of 20 to 33 per cent., and should be adapted for certain parts of motors.

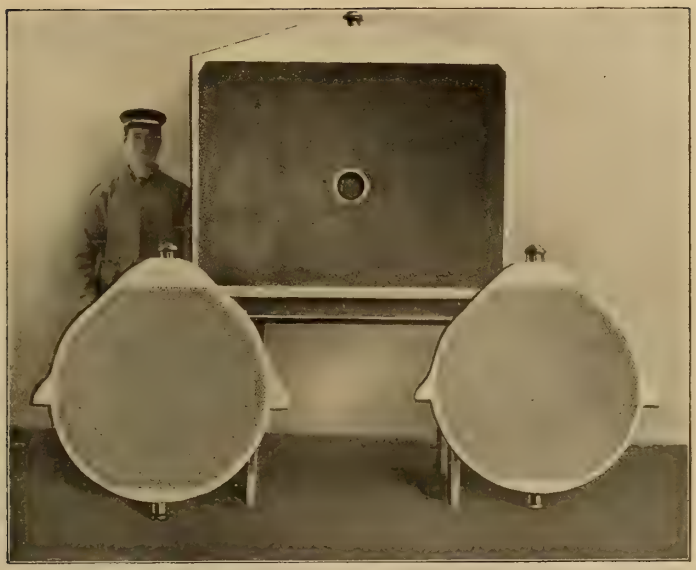
A new suggestion is made by August Bauschlicher, of Frankfort-Saxenhausen. He has succeeded in making aluminum sheet metal from 1/100 to 4/100 millimetre in thickness, and maintains that a balloon made of single fabric covered with such material would be quite gas-tight, and would not weigh more than if covered with a double india-rubber coated fabric, and at the same time would lose nothing in elasticity. Aluminum tubes lined with wood are shown by S. Rau, of Pforzheim, a combination which unites strength and lightness, the aluminum covering preserving the wood from the action of the weather. These combined tubes are lighter than those made of either wood or aluminum separately.

A number of interesting accessories are manufactured by Messrs. Basse & Selve, of Altena, in Westphalia, and exhibited by Mr. J. A. Kühn, of Frankfort, by whom their sale is controlled, these products relating to the combustion-motor industry. Foremost among them is an aluminum



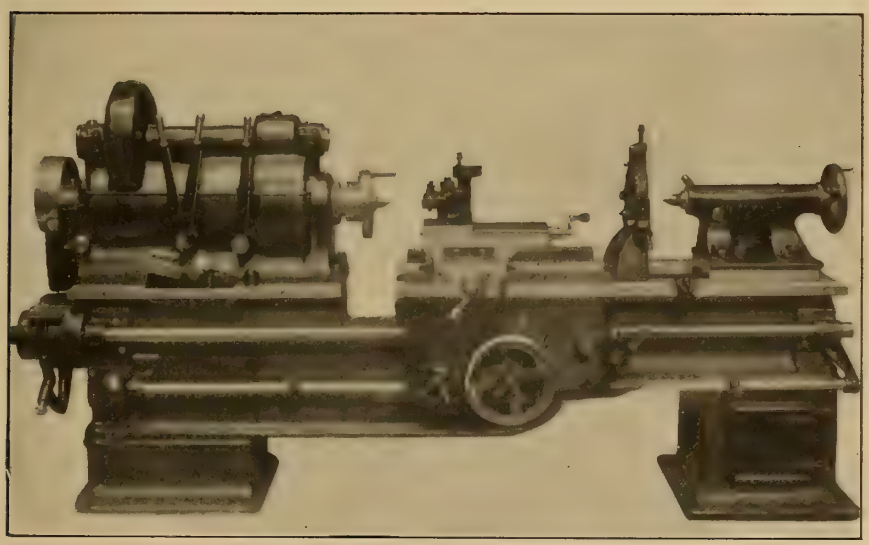
THREE STAGE-COMPRESSOR FOR HYDROGEN. MASCHINEN FABRIK, SURTH, NEAR COLOGNE

SCHUCKERT ELECTROLYTIC HYDROGEN GENERATING PLANT

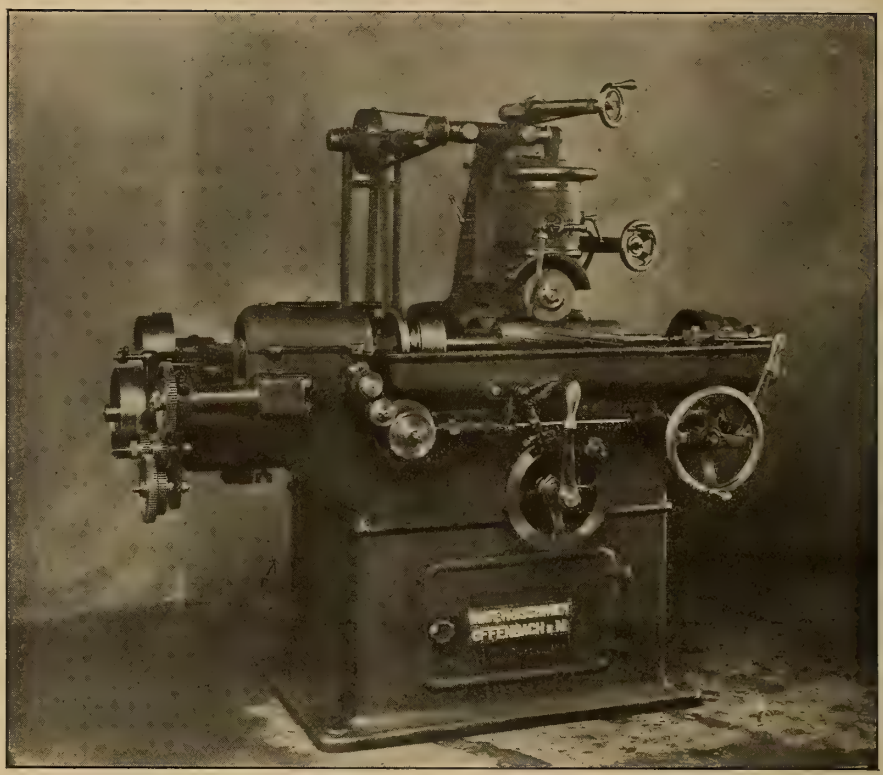


ALUMINUM RADIATOR FOR AIRSHIPS. BASSE & SELVE, ALTENA

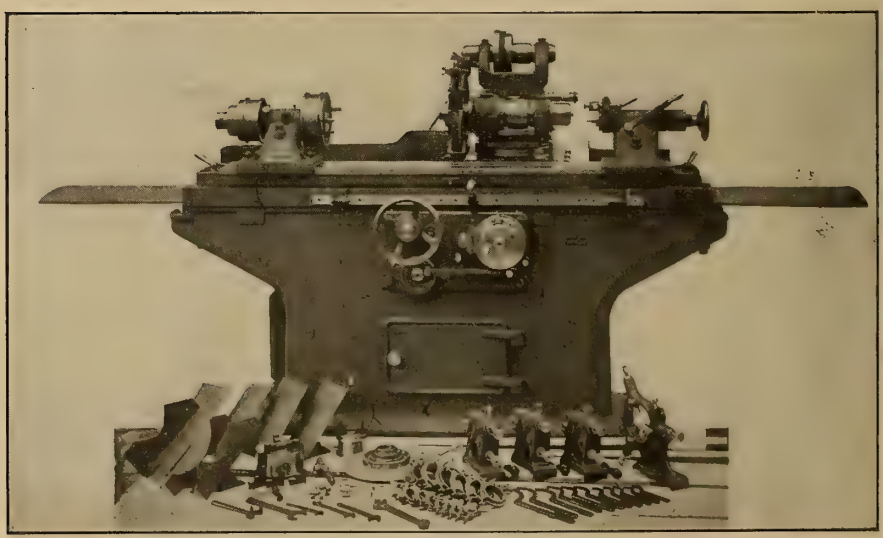
radiator having no soldered joints whatever. This aluminum radiator is made in sizes for automobile, airship and aeroplane purposes, and has the advantage of being about 40 per cent. lighter than if made of copper or brass, besides being more effective in cooling action. An especial advantage of the construction without soldering lies in the fact that in case of leakage a tube may be replaced in a few minutes. This radiator is used on several important types of airships, including those of Parseval, Gross and Zeppelin. Mr. Kühn exhibits a number of aluminum cast-



ENGINE LATHE. HEIDENREICH & HARBECK, HAMBURG



AUTOMATIC GRINDING MACHINE. MAYER & SCHMIDT, OFFENBACH, A./M.



AUTOMATIC GRINDING MACHINE. NAXES-UNION, FRANKFORT, A./M.

ings showing excellent moulding work. These show an elongation of 3 per cent. under test, a figure which is raised to 6 per cent. for drawn material, such as tubes and bars. This material is used by the Zeppelin Company in the construction of air-ships.

The exhibition also gives a good idea of the extent to which German manufacturers have met the demand for labour-saving machinery. Among the machine tools (exhibited by J. A. Kühn) is shown an engine lathe built by Heidenreich & Harbeck, of Hamburg, with positive feeds in the headstock, a machine which attracted much attention. This lathe, of only 18 inches swing, is provided with an electric motor of 8 horse-power. The positive feeds are controlled by three levers, which operate the gearing in the headstock. By means of frictions set between gears the speed of the headstock spindle may be changed instantly without stopping the machine. The grip of the frictions is well demonstrated by changing the speed from 90 to 240 revolutions in one direction, but a still better test is that of reversing the motion from 160 revolutions forward to 160 revolutions backward. The power of the machine was shown by its performance on steel of 90 kilogrammes tensile strength (about 128,000 pounds per square inch), from which it took a cut of ½ inch deep and 1/6 inch feed at a cutting rate of 24 metres per minute (nearly 80 feet per minute), this requiring 8 horse-power on the motor, the machine standing the effort without any chatter. The lathe has a change-gear box for screw-cutting, and all movements are readily controlled by the operator.

Messrs. Mayer & Schmidt, of Offenbach, showed a very strong and effective machine for roughing out and sharpening straight, spiral, conical and face milling cutters. It is capable of sharpening cutters up to 8 inches in diameter and reamers up to 24 inches long. The machine is fitted with automatic longitudinal movement of the table, self-acting and positive advance of teeth, and position guide for the spirals; the grinding head is placed at the back of the machine, and has an automatic forward and backward movement while it revolves on its axis. The spindle will take either a dish wheel for grinding cutters or an ordinary emery wheel for grinding and for grooving cutters, or a cup wheel for grinding the under side of the teeth of cutters. The tools to be ground are mounted on a mandrel between centres, and automatic spiral and dividing movements are provided.

A neat little machine, intended especially for grinding small circular saws, was exhibited by Fontaine & Co., Frankfort-Bockenheim. In this tool the apparatus operates continuously, both on the up and down movements, the grinding wheel rotating in fixed bearings and the up-and-down movement being given to the saw. The saws to be ground require no previous heating, and can be sharpened even if all the teeth are worn down or broken out.

A very solid and substantial grinding lathe is shown by the Naxos-Union, of Frankfort a. M., this machine having a longitudinal movement of the table and an automatic advance of the grinding head.

The grounds of the exhibition were traversed by a narrow-gauge railway constructed and operated by H. Janson & Hill, of Frankfort; the motors, of 16 horse-power, being made by Liebrecht & Co., of Mannheim, and the trailers by Max Strauss, of Karlsruhe.

CRANES AND HOISTING MACHINERY

By J. F. Springer

JUST what are the necessary and sufficient features of a crane is not so easy to say. Various types differ so radically from each other that a comprehensive definition that is not at the same time vague is rather difficult. However, this will not deter us from giving an account of some of them. The biologists have never been able to define *species,* and yet they go on with their science. Perhaps they are not usually careful to say that they do not know precisely what they mean by the word, and then, of course, they may do harm. We say, then, frankly that we hesitate to give a formal definition of a crane. But while this is the case, we will not shirk the duty entirely. A crane, then, may be described (if not defined) as an apparatus for hoisting and laterally transferring objects.

The earliest form is probably that of the bird from which the name is derived. The mode of operation here is very similar, in some respects, to that in certain of the most modern designs. Thus, the entire apparatus is movable. In any fixed position of the main body of the machine there is a flexible field of operation. And the intelligence which guides the "grabbing" apparatus is located in the immediate vicinity. Perhaps no single modern device has as yet been developed which is the equal of this ancient crane in absolute mobility of the main body and in ease and certainty of operation.

And if one searches the natural world, he will find many other examples conforming to our broad, descriptive definition of a combined hoisting and transferring mechanism. There are the human arm, the elephant's trunk, and so on.

Of the apparatus designed by man, perhaps the earliest crane was the old-fashioned well-sweep, of which the original was probably the Egyptian "Shadoof." The essentials here are a long pole supported near one end, a counterbalance attached to the short end, and a means of attaching the load to the long end. This is a very effective piece of apparatus. If we suppose it to be used for the purpose of raising water from a well, we may estimate the water at, say, 50 pounds. We will suppose the counterbalance to be of such a weight as not only to balance the unfilled bucket, but to exceed it by, say, 25 pounds. It is evident, then, that as we depress the long end, we must perform work in lifting the excess on the short end—either directly or indirectly. But this work is not lost; for, when the bucket is filled, it is utilized in the operation of lifting the load, giving material assistance. There have been many installations of cranes of this type. Probably some of these, with their old oaken buckets, are still in use in outlying districts.

Another early type of crane consisted of a cantilever boom rotating on a vertical axis. The weight is lifted by means of a rope passing over a pulley at the top of the boom back past a vertical dead roller over another pulley located in the operating house, and is then controlled by a windlass. The office of the vertical roller is obvious. The windlass is operated by a large drum in which one or more men performed treadmill duty. Joseph Glynn seems to have seen such cranes in use in Eng-

land as late as the early part of the nineteenth century. He states that the wheel was about 15 feet in diameter. To lower the load, the men would step backwards. But this operation had to be executed with some degree of care, as a racing load would tend to mix things up inside the drum. However, a bar of wood could be used to stop the drum if applied soon enough. The drum-treadmill seems to have been a very ancient device applied to the hoisting of heavy weights, as a description nearly two thousand years old is extant.

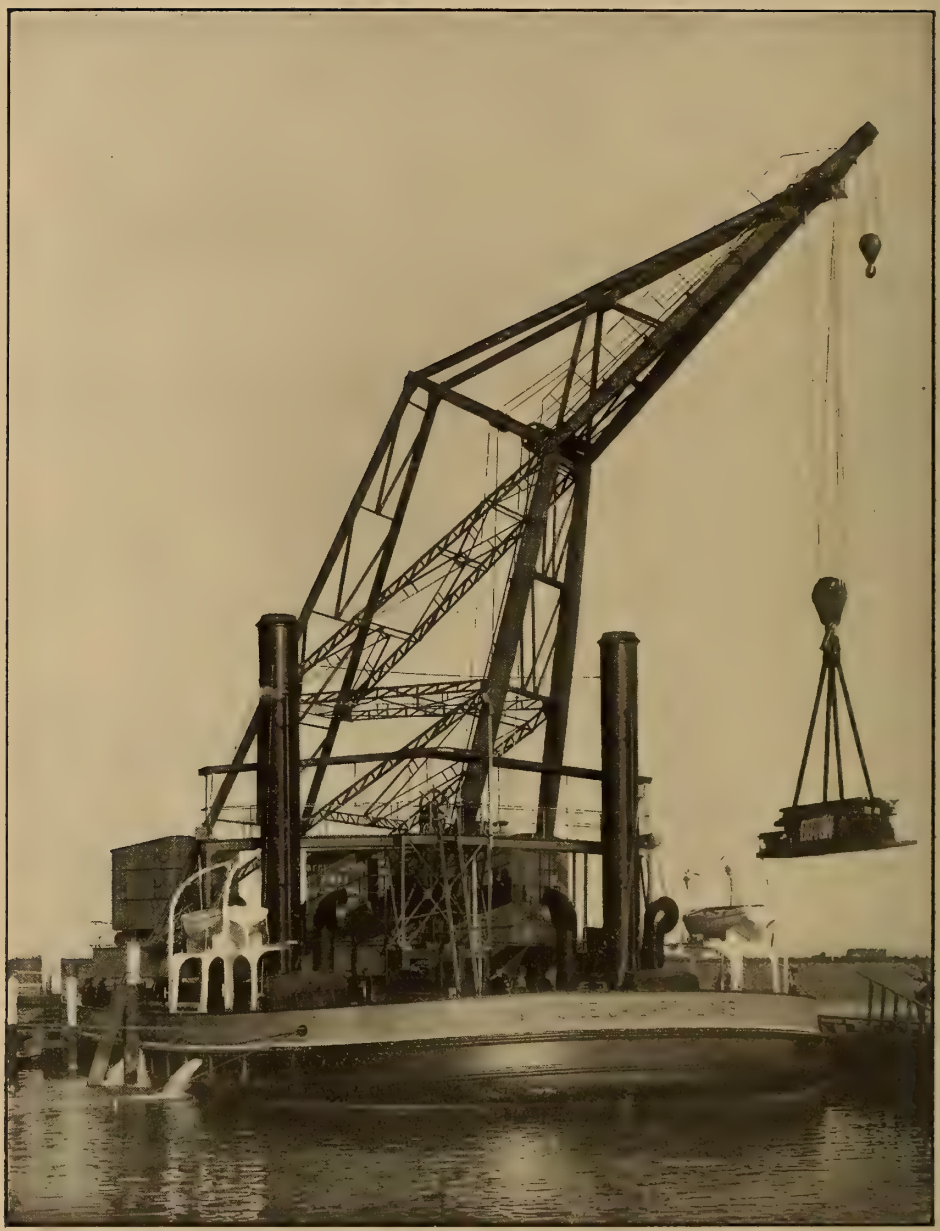
Primitive and rude as such apparatus may seem to us in the twentieth century, it is from such crude beginnings that our present wonderful devices have had their origin. The development of the crane has been greatly stimulated by the industrial requirements originating largely in the latter half of the nineteenth century. From the very earliest times men have always had need for some means of lifting heavy loads. In this they seem to have been fairly successful—as witness the elevation and weight of blocks in the pyramids of Egypt. But performing an operation is one thing and performing it at a reasonable expenditure of power and time is quite another. Great weights must have been lifted and put in place somehow. But at what expense? This is the modern question.

The query is receiving a concrete answer. At the present time there are probably few or no demands for the lifting and transportation of heavy objects that are unable to find some style or type of crane which will economically handle the weights in question. In some cases, indeed, development has proceeded so far that the cost seems ridiculously small. In others, the cost is still considerable, because the work to be done is only occasional and first cost for the apparatus is large. But after all is said and done, there is some reasonable solution for nearly every lift-and-transport problem.

FLOATING CRANES

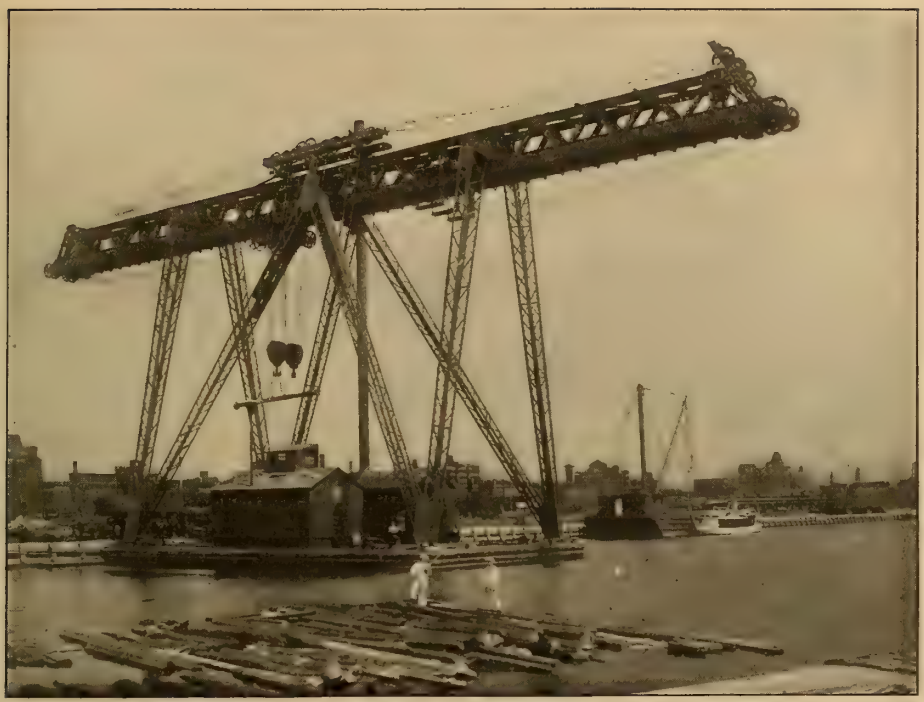
Two of the most recent developments in crane construction are the two large floating apparatus now in service at Buenos Ayres. It has happened at this port that objects could not be unloaded on account of the limited facilities for the work. In

STEAM-POWER STEEL DERRICK. AMERICAN HOIST AND DERRICK COMPANY, ST. PAUL, MINN.
Capacity 50 tons, radius 85 feet



FLOATING CRANE BUILT BY A. F. SMULDERS, SCHIEDAM, HOLLAND

consequence of conspicuous needs, the Argentine Government took the matter in hand and ordered from Messrs. A. F. Smulders, Schiedam, Holland, the 60-ton and the 100-ton cranes shown in the accompanying illustrations. Private firms are able to secure the use of these machines at moderate rates. From a constructive point of view, the two cranes are practically identical, so that a description of the larger is, in effect, a description of the other. The deck is of very strong construc-



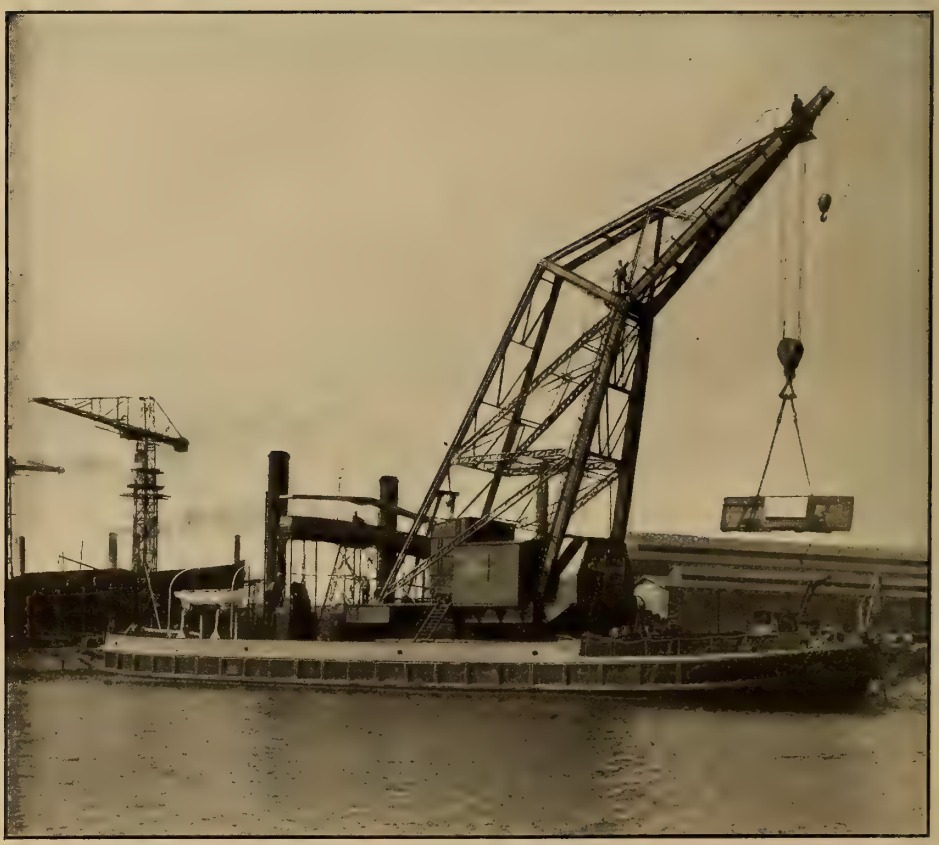
FLOATING CRANE HERCULES AT NAVY YARD, BROOKLYN, N. Y. BROWN HOISTING MACHINERY COMPANY, CLEVELAND, OHIO

tion, being capable of sustaining a pressure of 600 pounds and more per square foot. Upon the deck is placed a circular plate which serves as a foundation for the crane structure and running track. This running track is next the foundation, is made of cast steel, and has its surface planed so as to afford a smooth runway for the wheels which carry the superstructure. There are eight of these wheels, which are coupled in pairs. The platform and the goose-neck jib form the superstructure. It cannot be said that the form of the jib is very pleasing from an æsthetic point of view; but these two cranes are not parlor ornaments. Strength and lightness are prime requisites. And it can scarcely be denied that these have been effectively secured in the cantilever-like construction. It will be noticed that there are two hoisting cables. The one whose outermost pulley is at the extreme end of the jib is for 20-ton lifts, while the other is reserved for objects having greater weights, up to 100 and more tons. The hooks are attached to two-sheave and five-sheave blocks. The cables are operated by means of two sets of drums, which are driven by a winch. Power is supplied by a vertical compound engine having 12-inch and 23½-inch cylinders with a stroke of 14 inches.

The eight wheels which carry the jib and the load are of steel, and, as already indicated, have provided for them a smooth runway. The method of mounting is for the purpose of permitting the jib to be rotated without any movement of the hull. In order to secure this movement, a pinion secured to the platform engages with an annular set of 276 teeth arranged underneath the runway. The operation of swinging the jib round may be carried on at the same time with the hoisting movement. The rack-and-pinion device is controlled by a set of conical fric-

tion wheels. When the crane is lifting its maximum load of 100 tons, this weight is supported at a radial distance of more than 30 feet outside the area of the base. The distance from the side of the hull may amount to 26 feet. Remembering that both the wheel base and the boat are nothing more than movable supports, it will be seen that an absolute requirement of construction and management is that the centre of gravity shall forever lie within the wheel runway. A counterweight of 250 tons is placed on the platform. This is mounted on eight wheels, coupled in pairs. The counterweight is a steel case filled with rails, and is controlled by an engine having two high-pressure cylinders 7 inches in diameter and having a stroke of 8 inches. The to-and-fro action is not automatic, but is controlled by the craneman. This man has in front of him a very sensitive water-level, which enables him to determine any tendency to depart from the horizontal. His left hand rests on the regulator controlling the speed of the hoisting apparatus, his right hand commands the mechanism which controls the movement of the counterweight. He can ascertain by means of a scale, without leaving his post, the position of load and counterweight.

These floating cranes are fitted with engines sufficiently powerful to give them a speed of more than 9 miles per hour. In the official trials the larger crane lifted its load of 100 tons at the rate of 5 feet per minute to a position where the centre of the corresponding sheave was 78 feet

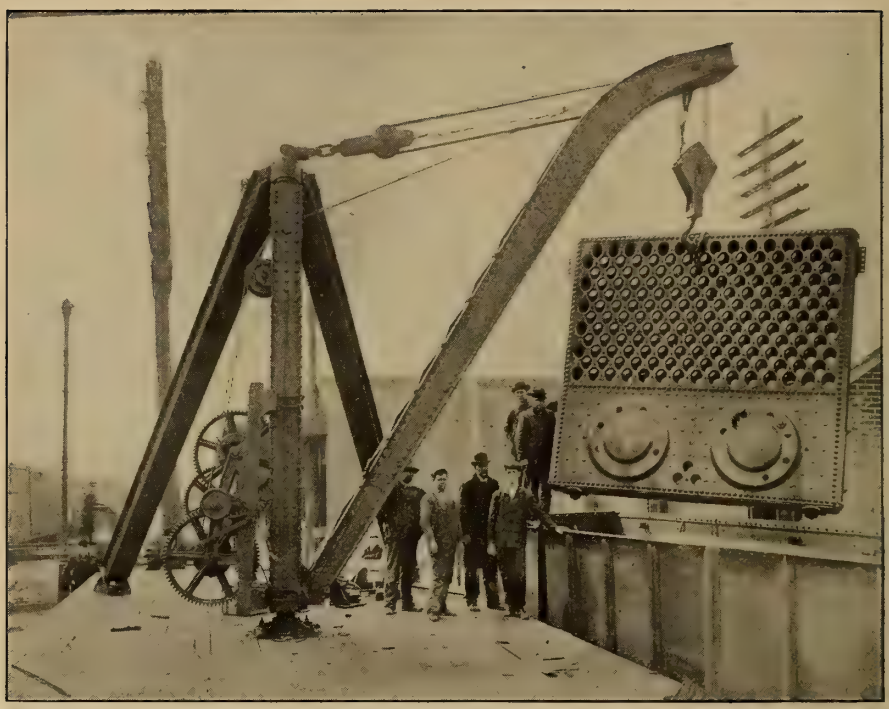


FLOATING CRANE BUILT BY A. F. SMULDERS, SCHIEDAM, HOLLAND

ELECTRICALLY-DRIVEN STEEL DERRICK. AMERICAN HOIST AND DERRICK COMPANY, ST. PAUL, MINN.

9 inches above the water. The load was swung round in either direction in less than three minutes. The 20-ton weight was lifted at a speed nearly three times as great. The trials of the smaller crane proved equally satisfactory. With superstructures in position, both cranes steamed from Holland to Buenos Ayres.

It will readily be seen that the operation of these devices involves skilled and careful attention. Apparently a slight error in moving the counterweight might have disastrous results. However, the counterweight never overhangs the deck at any point of the swinging movement; and, further, there are automatic means for stopping the engine before an extreme position is taken up. The great floating crane *Hercules,* stationed at the United States Navy Yard at New York, is a notable example of its class. This apparatus was built by the Brown Hoisting Machinery Company, Cleveland, Ohio. The pontoon is of steel, 100 feet long, 60 feet in width, and has a depth of 11 feet 3 inches. As the bridge is about 200 feet long, there is an overhang of 50 feet at each end. Not quite the whole of this is effective, however, the maximum horizontal distance from the end of pontoon to centres of sheave blocks being 45 feet. From each corner of the float two steel struts rise obliquely to support the bridge. These are so arranged that a considerable clear space is left from end to end, notwithstanding certain deck encumbrances. Upon referring to the accompanying illustration, the boiler house and stack may be seen towards the back of the picture upon the starboard side of the pontoon. In the foreground, on the port side, is the engine house. A trolley runs along the bridge and supports the two great sheave blocks. Each block contains four sheaves and is independently operated. There are four dozen guide sheaves distributed through the apparatus. There is, in all, something over a mile of steel cable 1⅛ inches in diameter. The twin blocks may be raised 64 feet above the surface of the water or lowered 22 feet below, giving an extreme range of 86 feet. The great counterweight of 250 tons traverses the pontoon longitudinally between



STEEL CRANE BUILT BY THE AMERICAN HOIST AND DERRICK COMPANY.
Capacity 20 tons, radius 23 feet

engine and boiler. It is controlled automatically by a throttling engine. It will be observed that the position of the bridge is fixed relatively to the pontoon. However, a transfer of the load from one end of the bridge to the other is equivalent to a swing of 180 degrees. Intermediate movements may be obtained by management of the pontoon—alone, or in connection with a movement along the bridge. This crane is capable of lifting, with its pair of blocks acting together, 100 long tons. It is said, however, that each block can carry, upon occasion, 60 long tons. Such a piece of machinery costs about $25,000 and weighs about 1,200 tons.

This crane has proved an effective piece of apparatus. It has removed a 13-inch gun from a battleship, deposited it on its own deck, transported it thus to Jersey City, exchanged it there for another gun, which it brought to the Navy Yard and put in place on the ship. The actual cost of this performance is said to have been no more than $200. The government is so well pleased with this type of floating crane that it has ordered another to be built along the same lines by the Wellman-Seaver-Morgan Company.

HAMMER CRANES

Some very powerful cranes of the "hammer" type are in use in Europe. This name is, no doubt, applied as descriptive of the general appearance of the whole structure. One is at the shipyard of J. Brown & Co., Ltd., Clydebank, Scotland. It has a capacity of 150 tons lift, and was built by the Glasgow firm of Sir William Arrol & Co., Ltd. There is a square tower of structural shapes erected at the foot of a pier. Upon this tower—which is the handle of the hammer—the framework is rotatably mounted, which constitutes the hammer's head. There is a short

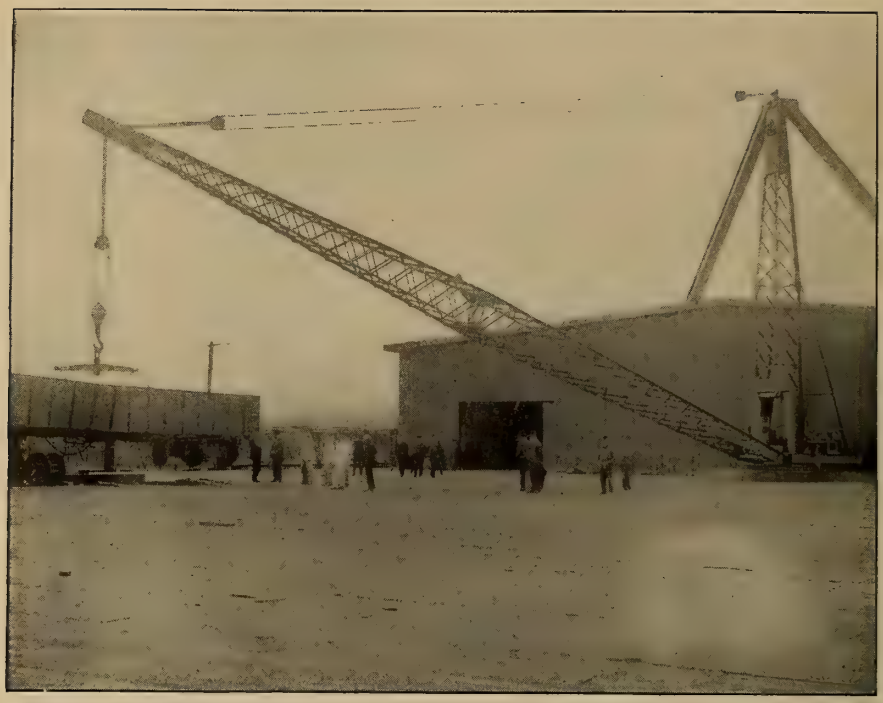
and a long arm, the former containing the necessary counterweight to offset the load which traverses the latter. There are three motions to be provided for by the electric motors: the hoisting apparatus proper, sometimes called the "crab," the traversing movement of the crab along the arm or jib of the crane, and the turning movement of the cantilever arms.

This giant crane has a length of arm on the lifting side of 148 feet. The short or balancing arm is 90 feet in length. From top of wall of the quay to the rails on which the "crab" runs is 156 feet. These dimensions manifest the wide range of operation of this electric apparatus. There are other types of cranes which require three motions, these motions differing greatly in the requirements they impose. The most powerful effort in the operation of all such cranes is, undoubtedly, that of the lifting of the load. Usually the three diverse requirements are met by the use of three distinct motors.

Another electric crane of the hammer type is the 150-ton machine designed by the Benrath Engineering Company, Benrath and London. There have been a number of installations of such cranes, and they are similar in general appearance to the one just described.

One of the most powerful cranes ever built is of the hammer type. This is the giant crane at Bremerhaven, Germany. It has been tested with a load of 220 short tons. There is a pyramidal tower of structural shapes. This is fixed in position. The hammer-head is not carried by the top of the tower, as is the case with the similar crane at the yard of J. Brown & Co., Ltd. Instead, there is a handle-like structure which projects downwards and within the framework of the tower. This arrangement permits the load to find its support at the base. There is, however, a maximum horizontal pressure at the top of the tower, which has been estimated to amount to about 100 tons. The pressure exerted by

ELECTRICALLY-DRIVEN STEEL DERRICK. AMERICAN HOIST AND DERRICK COMPANY, ST. PAUL, MINN.



ELECTRICALLY-DRIVEN STEEL DERRICK. AMERICAN HOIST AND DERRICK COMPANY, ST. PAUL, MINN.

means of the central projection or "handle" may amount to more than 500 tons. To carry this load and permit a rotary movement, an immense roller bearing is provided. This consists of thirty-five hardened steel rollers arranged between two roller raceways. These steel rollers are about 10 inches in length, conical in form, and have a central diameter of about 7 inches. They are set in raceways whose outside diameters measure about 8 feet 1 inch. Apparently, then, the rollers have a taper such that, if the elements of their surfaces be produced until intersection at the vertical axis of the crane, an angle of about 9 degrees would be inclined between any pair of opposite elements. There is a plentiful supply of oil to reduce friction to a small amount. The bearing is not rigidly connected with the "handle" of the hammer for the following reason: It is inevitable that during the operation of lifting there would be an inequality of pressure on the bearing if a rigid construction were adhered to. To avoid this, the upper surface of the upper "washer" of the roller thrust bearing is separated from immediate contact with the bottom of the handle. Both parts are reduced in diameter. Between them, in a cylindrical groove—half in one and half in the other—is placed a pin. The axis of this pin is perpendicular to the axis of the head of the hammer. As the two grooves do not quite complete a perfect cylinder, the pin has the effect of forming a kind of hinge, and so permitting slight lateral movements of the "handle." But the load delivered to the roller bearing is forever approximately central. In this way an approach to equality of pressure throughout the bearing is attained. There is another roller bearing at the top of the tower. Eight rollers are journaled in a frame connected with the "handle." This crane

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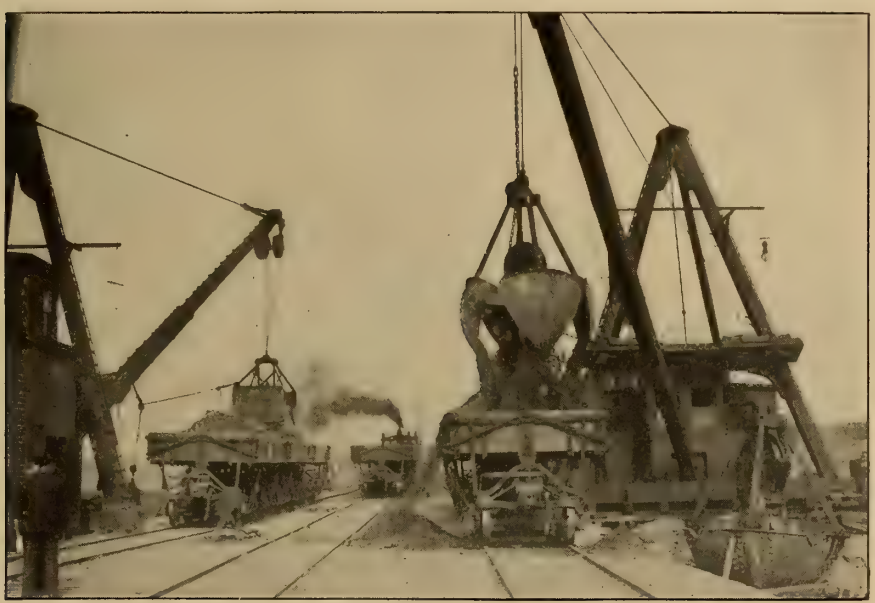
PORTABLE CRANE. BROWN HOISTING COMPANY, CLEVELAND, OHIO

is electrically driven throughout. It is usually the case that the lifting effort is the greatest. In this crane two motors are provided for the purpose. The traversing movement along the arm has a separate motor. The three are all enclosed in the "crab." A fourth motor is employed



ORANGE PEEL BUCKET LOADING CAR. HAYWARD COMPANY, NEW YORK

to accomplish the rotary movement. The double-arm, which constitutes the "head" of the hammer, is 164 feet long. The maximum horizontal radius to centre of load is about 72 feet. From the surface of the ground to the rails above is about 115 feet. The entire weight, inclusive of the great counterbalance, is about 475 tons.

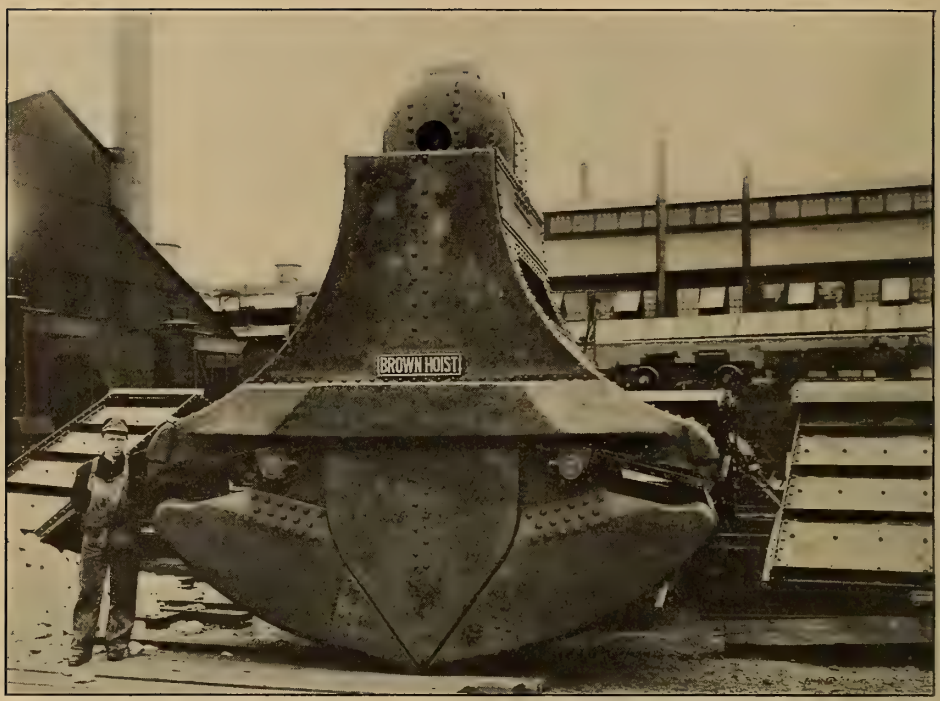
THE GRAB-BUCKET

The crane would be an apparatus of much more restricted application if it were not for the grab-bucket. The fundamental idea is a device which will perform its own loading and unloading operations. The problem of unloading, if it had existed alone, would not have been formidable. If the receptacle were an open bucket, it required nothing more than turning over or letting go on a hinged bottom. Under any circumstances, we may well assume that it is the loading operation which calls for inventive genius. Two methods of performing this mark the modern bucket. In the one process reliance is largely placed upon the penetrative action of the bucket dropped upon the material. A good type of this is the orange-peel bucket manufactured by the Hayward Company. A bucket of this type is shown in the illustration in action, loading a car on the right. The scene of this picture is a dock at the Harrison Terminal, New Jersey, where the Hackensack River empties into Newark Bay. Here and at Greenville is to be located a gigantic freight terminal of the Pennsylvania Railroad. A large fill is a part of the project. The material for this has come largely from the excavation for the Pennsylvania Railroad's passenger station under construction in New York City. To handle material to advantage, a long dock, capable of accommodating at either side an 800 cubic yard barge, was constructed. Upon this were mounted two unloading machines,

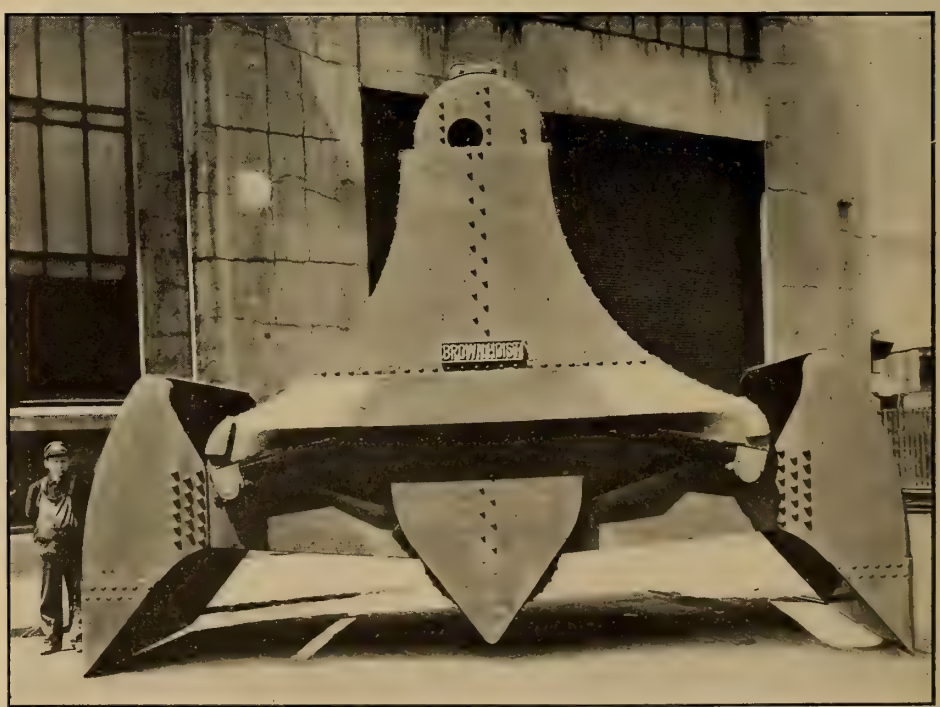
HULETT UNLOADERS WITH CLAMSHELL BUCKET. WELLMAN-SEAVER-MORGAN COMPANY, CLEVELAND, OHIO

CLAMSHELL BUCKET DUMPING CLAY. HAYWARD COMPANY, NEW YORK

each commanding one barge and two-thirds the width of the dock. Three standard-gauge railway tracks run along its length. It will be noticed that upon the left a different type of bucket is in use. This is the clamshell variety. The orange-peel style is well suited for unloading where the depth of material is considerable. When the amount of material begins to run low, the clamshell bucket is more advantageous. So, at this dock, the orange-peel bucket performs the unloading operation up to a certain point, when the barge is moved to the other side of the dock, where the clamshell bucket completes the duty. In this way each type of bucket is used to advantage. It is worthy of note that the central track has a great economic value in that it permits continuation of operation even though cars on the marginal tracks may be filled and no locomotive available at the moment for their removal. At the instant of the photograph an "empty" is being run in on the central track by a locomotive. The capacity of the clamshell bucket is about two and one-half cubic yards. Another illustration shows a clamshell bucket dumping clay which it has just dredged from the bottom of the East River, New York City. This is



BROWN HOIST GRAB BUCKET IN CLOSED POSITION



HEAVY GRAB-BUCKET OF 250 CUBIC FEET CAPACITY (OPEN). BROWN HOISTING AND CONVEYING COMPANY, CLEVELAND, OHIO

likewise a Hayward bucket of about two and one-half yards capacity. The bucket is being operated by a locomotive crane mounted on a scow. The clay has been deposited over the Pennsylvania Railroad tube under the river, and, having served its purpose, it became necessary to remove it. This illustration will show the adaptability of both the locomotive crane and the grab-bucket for this subaqueous service.

A style of bucket quite distinct from the orange-peel type has been developed by the Brown Hoisting Machinery Company. The illustration shows one of the largest buckets ever constructed. It has a capacity of 250 cubic feet, or 9.3 cubic yards. An idea of its size may be gathered

STEAM-OPERATED CLAMSHELL BUCKET. McMYLER MANUFACTURING COMPANY, CLEVELAND, OHIO

by comparing it with the men alongside. This same bucket may be seen endwise suspended from the great bridge crane of the Astoria Light, Heat & Power Company, Astoria, New York City. Here, likewise, an idea of its size may be gotten by comparing with the man standing erect upon the platform of the cab above. In operation, this type of bucket does not depend upon its penetrating action, but upon a shoveling movement of the two leaves. These approach each other with their under surfaces approximately horizontal. In fact, it is stated there is difficulty in preventing this bucket from overfilling, so complete is the shoveling action. Another type of clamshell bucket is built by the McMyler Manufacturing Company. This bucket is fitted with teeth and operated by steam. A novel bucket is used in connection with the Hulett unloaders built by the Wellman-Seaver-Morgan Company. This appears in the view shown in the hold of the great steamship the *Augustus B. Wolvin,* engaged in ore-carrying on the Great Lakes. The operator is seen in the tube, whence he is able to control the operations of the great double-shovel to advantage. This device has made possible what is probably the greatest unloading apparatus the world has seen.

(To be concluded.)

THE EVOLUTION OF THE PLANING MACHINE–I.

By Thomas R. Shaw

THE nineteenth century was remarkable for being a distinctly mechanical era. At the beginning, the machine shop scarcely existed, except in the most primitive form, and machinery of any but the crudest types was practically unknown. Likewise, means of transportation were effected by crude carts or wagons on land, and by wind pressure or hand propulsion on sea. The steam engine was just beginning to be recognized as a prime mover, but was generally unknown.

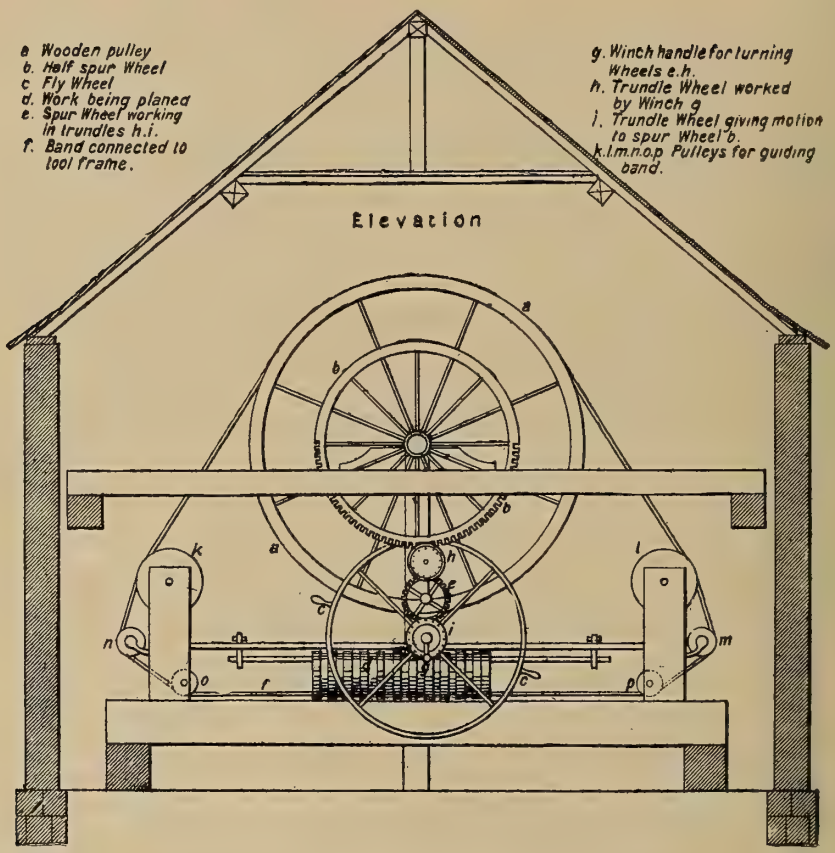
The end of the century showed a remarkable change. The steamship, locomotive, electric car and automobile have come to be necessities for transportation, and in every industry that then existed, nearly every feature has been changed. As a result of the general mechanical development, many new industries have come into existence. The building of machinery requires machine tools and the machine shop; this has become a necessity, and has so developed that it is now an important factor in every industry, and directly or indirectly influences every trade and profession.

Like all other accomplishments of modern civilization, machine tools in their present forms are the result of a progress of slow development. A machine does not spring full-fledged into existence, but is gradually evolved from some original type, gaining here and there a useful member and losing here and there a superfluous one, thus illustrating the survival of the fittest.

The early machine tools were of the crudest workmanship, and many parts were made of wood. In fact, the transition from wood to iron in the construction of machinery was in progress during the early part of this last century, and the formation of much of the machinery built at that time involved the conversion of structural shapes required for wooden machines into similar shapes in metal. In the first change from wood, architectural shapes and ornamentation were considered desirable, to make machine tools and other machinery meet what seems to us now the rather barbaric taste of those who were to use them. In some cases, beds and uprights were paneled; in others, they were decorated with fancy curves and intricate mouldings, and show a remarkable contrast with the plain, sturdy framework of today.

The lathe had that most important improvement made in it, viz., the invention of the slide rest by Henry Maudslay, in 1794, which caused the cutting tool, previously held in the uncertain grasp of a workman's hand, to be held in a hand of iron. It furnished the means of grinding the cutting point in mathematically straight lines and made accuracy possible.

What was looked upon as a most important, and probably the immediate offspring of the slide rest, was the planing machine, a machine which, it has been said, has done more in reducing the cost and extending the use of perfect machinery than all the improvements effected in mechanism in the past two hundred years, there being few machines or engines in which the plane surface is not the form most essential to perfect action or not most frequently required. Here it is interesting to note that Bramah had been making ma-


a Wooden pulley
b. Half spur Wheel
c Fly Wheel
d. Work being planed
e. Spur Wheel working in trundles h.i.
f. Band connected to tool frame.
g. Winch handle for turning Wheels e.h.
h. Trundle Wheel worked by Winch g
i. Trundle Wheel giving motion to spur Wheel b.
k.l.m.n.o.p Pulleys for guiding band.
Elevation

FORQ'S PLANING MACHINE, 1751

chinery since 1782, and that in 1789 Maudslay was a foreman with him, and continued so for eight years, until he started for himself in 1797. It was a wonder how it was possible for a machine works to produce any large amount of machinery without the planing machine. Even allowing that shipping and filing were resorted to, and perhaps with greater skill than could be found now, we can hardly, at the present time, fully picture by what methods the results were arrived at in making lathes, with their beds, slide rest, etc., and the other details. There must have been large quantities of machinery, requiring accuracy in the surfaces, made before the planing machine was at work. The cost of preparing flat surfaces by hand—a thing now so rare as to be unknown to mechanics—at the time of introducing planing machines was about 12 shillings per square foot at the low rate of wages then paid. So an incentive for producing and improving planing machines was not wanting.

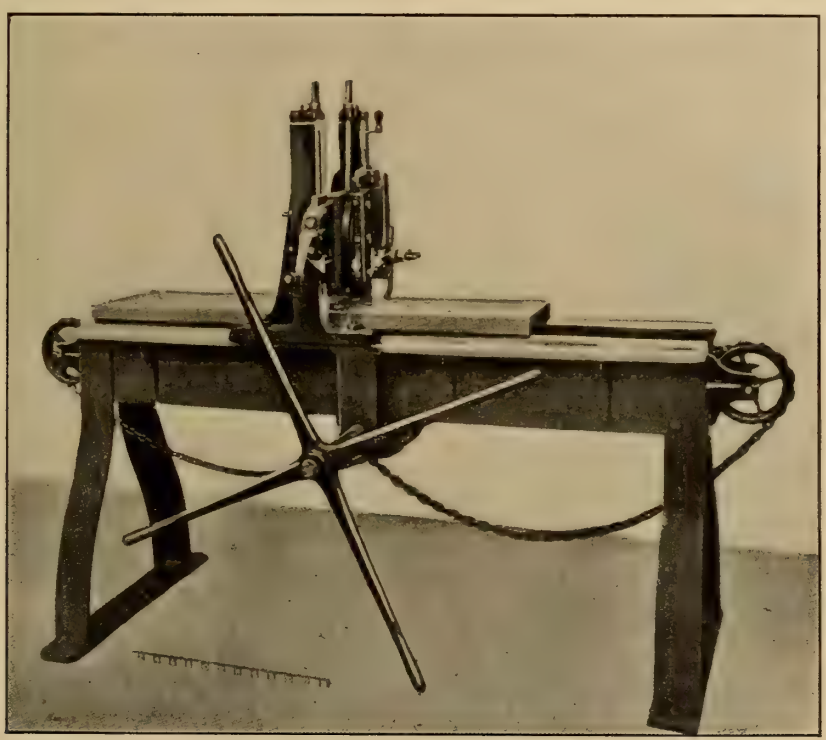
The vast expense attending the production of a plane surface by the tedious process of shipping and filing caused most of the early engineers to avoid all constructions which rendered such forms necessary; this practice was, however, soon altered on the introduction of the planing machine, which did for the plane surface what the slide rest had effected for cylindrical forms, the result being that machinery produced by its agency was not only infinitely superior, but improved tools were

made at a far less cost, as the first planing machine helped in the production of a still better second, and that again a better still, so that very shortly an entirely new branch of engineering business was established, viz., that of machine-tool making.

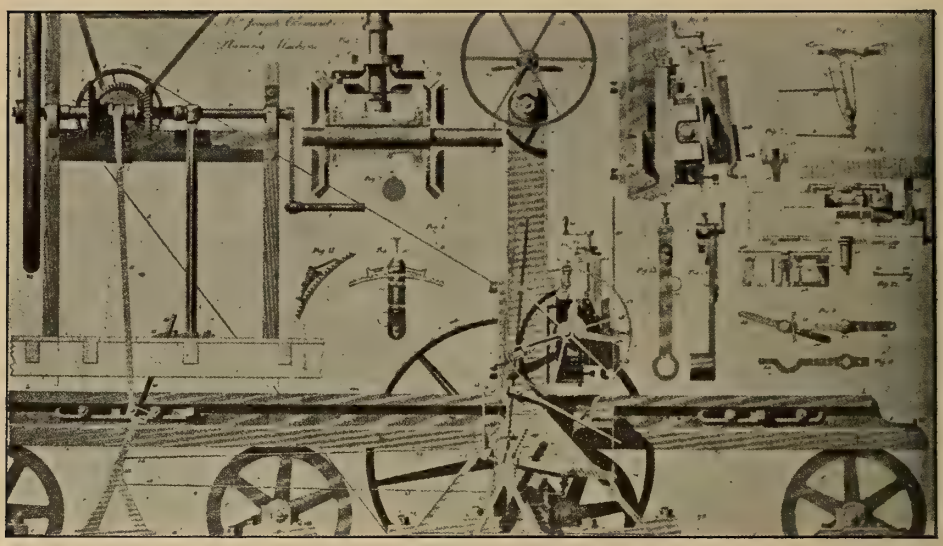
Now as the early engineers, when called upon to supply, or required for their own use, a tool of an entirely new type, had no precedent to guide them as to the parts actually necessary in such a contrivance, or to the form the machine or its parts should assume, it is not surprising to find that the earliest machines for metal planing should have been given somewhat different forms, although embodied in them were the same fundamental principles and modes of action. The parts common to the earliest of them were principally two in number, viz., the bed, on which a table carrying the work to be planed was caused to slide backwards and forwards on guides, and a main slide carrying a traverse one and tool-holder, which was held in position by being bolted at its ends to upright standards attached to the machine bed on either side. An alternating motion was usually imparted to the table of the early machine by a chain wound round a drum, which was revolved first in one direction and then in the other by hand.

As to the original inventor of the planing machine, there is, perhaps, scarcely a machine about which there has been more controversy than this, and there are many claimants to the honour. There are records showing that Nicholas Forq, a French clockmaker, used a metal planer in 1751 for machining pump cylinders, apparently being under the impression that they could be made more accurately in this manner than by a revolving cutter.

Joseph Bramah patented a planer



ROBERTS' PLANING MACHINE, 1817



CLEMENT'S PLANING MACHINE, 1820

in 1802 with a revolving cutter; but it was primarily designed for wood, and appears to have been used for this purpose.

It is claimed by some that James Fox, of Derby, made the first metal planing machine in 1814. Another claimant is Matthew Murray, of Leeds. Mr. March, head of a once celebrated firm of tool-makers in that city, has recorded that when he first went to work there in 1814, a planer of Murray's invention was used to plane the back of the "D" slide valve of the steam engine. Mr. March says: "I recollect it very distinctly, and even the sort of framing on which it stood. The machine was not patented, and, like many inventions in those days, it was kept as much a secret as possible, being locked up in a room by itself, to which the ordinary workman could not obtain access. The year in which I remember it being in use was, so far as I am aware, long before any planing machine of a similar kind had been invented."

Next in the list comes Richard Roberts, of Manchester, who constructed a planing machine on an original plan of his own in 1817. This machine is said to be the first one ever made for the planing of metal, and is exhibited at the South Kensington Museum. That the machine may claim for itself priority of existence over any other devised for the same purpose is evidenced by the hand tool and other marks to be seen on its bed, which plainly show that no previous planer had been used in its construction.

On an inspection of the illustration, it will be noted that the bed of the machine consists of two cast-metal cheeks of angle-bar form, stiffened by bracketing, and bolted to cast-metal supports of the form shown. The table traverses on inverted V-guides cast on the bed top, and is moved by hand to and fro by means of a chain passing over sheaves at the ends of the bed and wound on and off the drum of a winch placed midways in the length of the bed, being turned by the four-armed handle, as shown. There are two uprights to carry the cross-slide, and each is slotted through to enable the cross-slide to be firmly bolted thereto and to form the guides when raising or lowering the cross-slide.

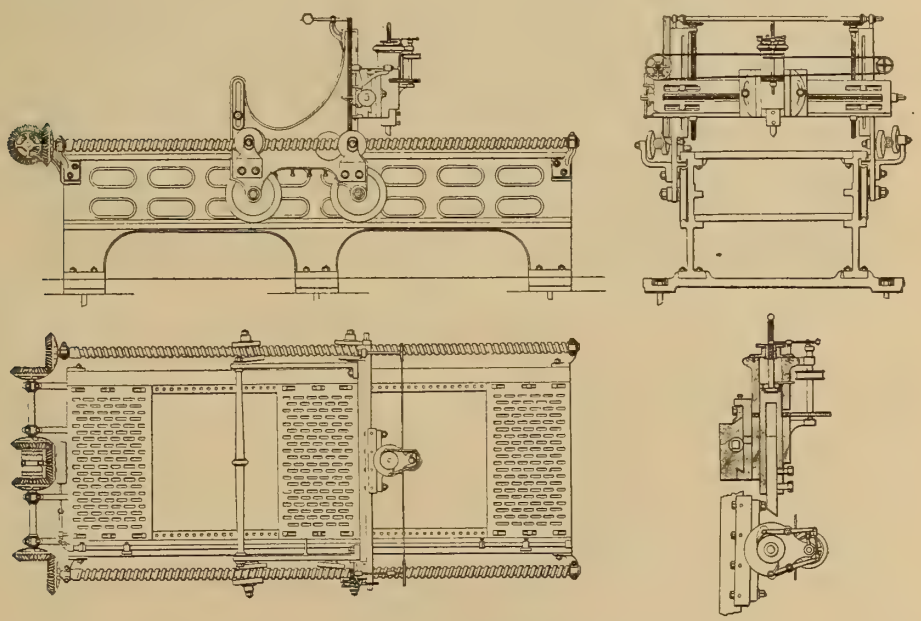
It is Clement, however, that the honour is usually accredited of bringing out the first iron planer on the

same lines as the tool is now built. He had a machine for planing the triangular beds of lathes in 1820, and in 1825 built a more elaborate one, which is described in a paper read before the Society of Arts during the session of 1831 and 1832.

This paper commences as follows: "The engineers' planing machine is used to cut metal so as to produce clean and perfectly straight or flat surfaces. It differs greatly from the carpenter's tool called a plane, the length and straightness of which prevent the cutter from descending into any hollows; it, therefore, gradually reduces the prominencies, and the cutter is never allowed to project through deeper than the thickness of the shaving, which the workmen can safely take off without tearing up the grain of the wood. The wider such a plane is, the flatter it will work; but, as the resistance increases with the width of the cutter, this latter rarely exceeds two inches, or two and a half; for beyond that the weight and strength of a man are not sufficient to overcome the resistance."

After thus preparing the minds of the members as to the existing conception of the planing art, the paper goes on to say: "The planing machine about to be described bears more analogy to the turning lathe; it performs its work in right lines, and is so constructed that during longitudinal cuts the tool is stationary and the work moves, but during lateral cuts the tool moves. The tools or cutters are similar to those used at the lathe, their forms being in like manner varied from a strong point to a chisel-shaped edge to finish the work."

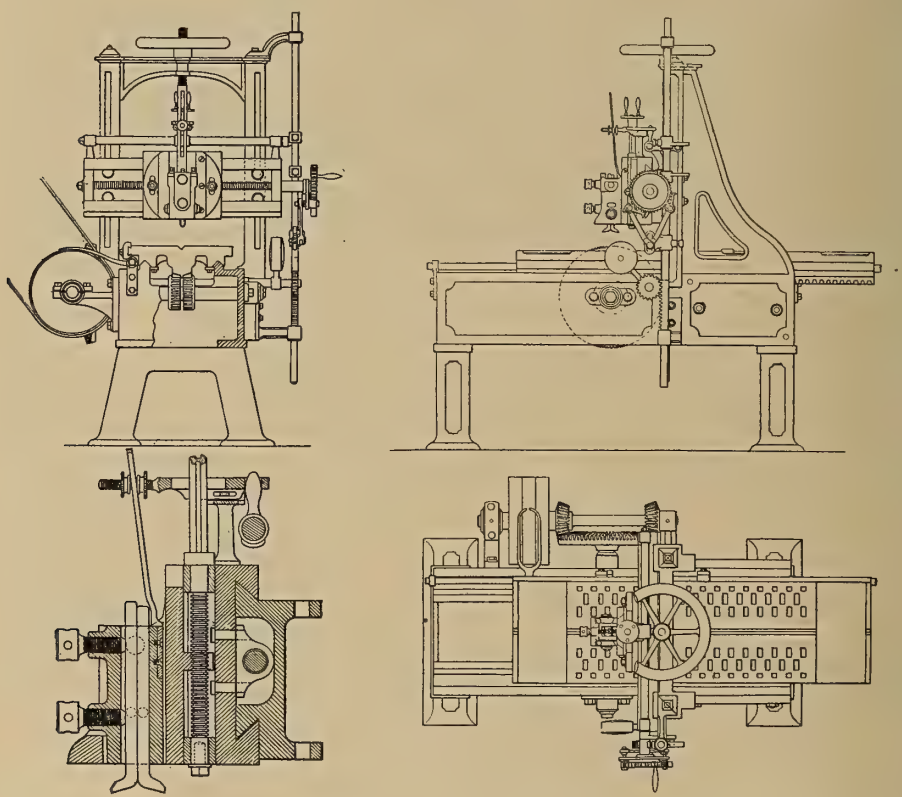
Clement, with a view to remove as far as possible the friction and labour due to the travel of the table, caused the table of his machine to pass under the cutting tools on perfectly true rollers or wheels, which were held in accurately made bearings, having setscrews acting against the ends to prevent all endwise motion. He also saves or uses the whole time by taking cuts both ways, there being two tools mounted in the tool box, "one to cut while going, the



EARLY WHITWORTH MACHINE, 1835

other when returning," as the description explains the to and fro movement of the table.

Clement clearly recognized the necessary conditions under which planing could be correctly done. As can be imagined, freedom from friction in moving the table and the pieces to be planed was of far greater consideration than at present, hence and solid foundation under his machine. The language of the paper is particularly clear when it says: "It was requisite to obtain a very perfect base to build on, one that would not bend, spring, or yield in any way to the most unequal loads that were liable to be put on it; and, as a rock exceeds all others for the purpose, Mr. Clement began by lay-



ROBERTS' MODERN-TYPE PLANER, 1839

the table on friction rollers. But rigidity in the parts and perfect fitting of the bedding surfaces are clearly specified as necessary to "destroy all tendency to vibration and thereby obtain full, sound and quiet cuts."

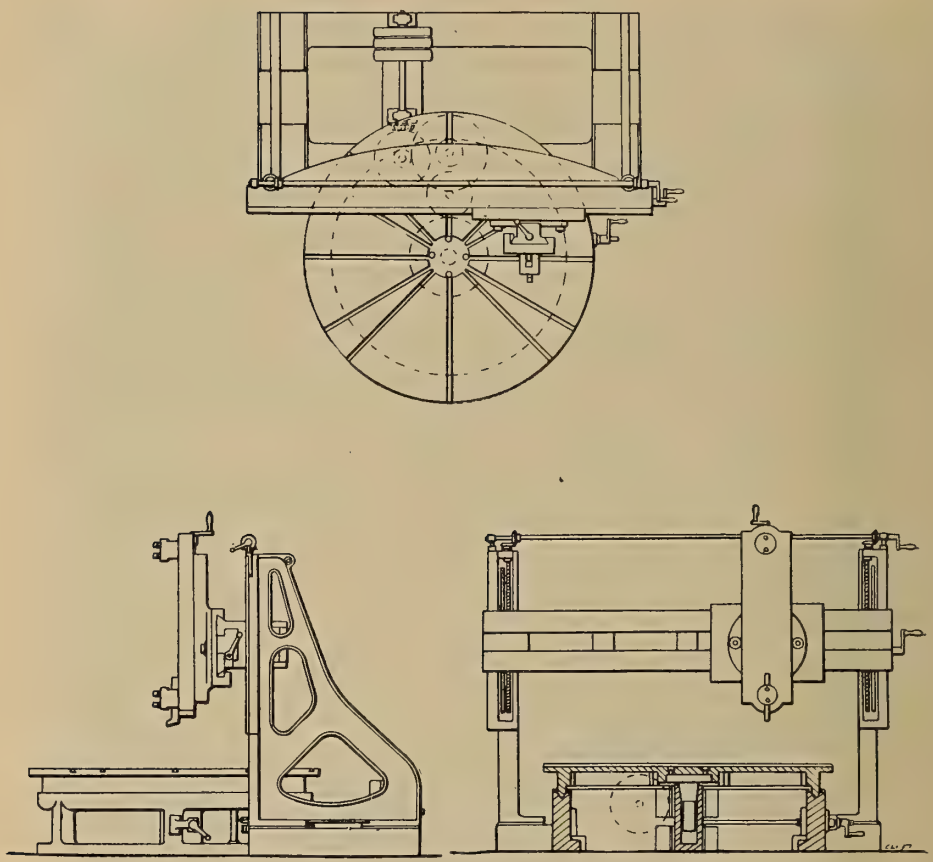
It is very easy for us, with over seventy years' experience since then, to see where Clement failed to embody that rigidity he had in view; but in other ways we cannot help appreciating the feature of a good ing in the earth an artificial rock, or bed of masonry, with an iron surface large enough to give confidence to the superstructure." Confidence, as referring to the stability of the parts of the machine, is a rather happy expression. One of Clement's original drawings, showing side view and details of his machines, is reproduced in this article.

Looking at this view, we must at once realize the side weakness of the

WHITWORTH PLANER WITH "JIM CROW" TOOL BOX, 1859

whole construction. Instead of a bed to support the table and tie the uprights together at the bottom, we have the space occupied by the roller wheels to carry the table. The uprights are also without much stiffness in the direction of the cuts, being quite parallel from bottom to top, evidently to accommodate the clamping plates which hold the cross-slide. The description of the machine gives these uprights a good character, as they are referred to as "strictly upright standards."

The table is driven by two racks with small pinions, which are apparently solid with the shaft. There are no complications in the driving of the table, as a large pulley is keyed directly to the rack pinion shaft. This is driven from an overhead countershaft carrying a reversing



BODMER'S BORING MILL OR CIRCULAR PLANER, 1839

motion in the shape of three mitre wheels and a sliding claw clutch. At the end of the stroke the machine reversed automatically.

Clement mounted his cross-slide in trunnion bearings at each end, so that by tipping this slightly at the end of each stroke the tools at the back and front on the cross-slide could be brought into position for cutting. The section shows the left-hand tool in position.

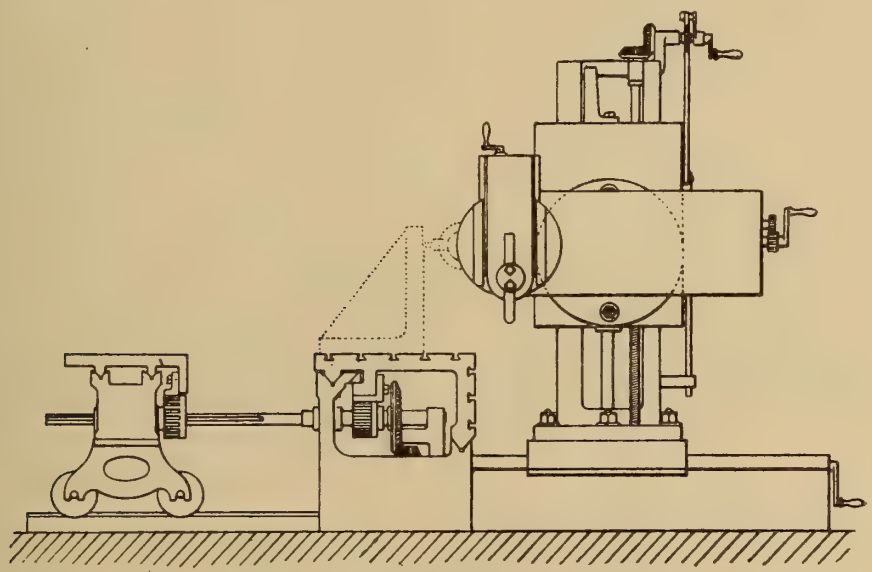
Clement had another kind of cross-slide to fit to his machine in the place of the tilting cross-slide shown, which corresponded closely to the standard construction of to-day. The tool-box saddle on this was very long, because the machine was used for cross-planing at right angles to the table. This cross-slide was also used, by attaching it to the vertical face of the upright, for vertical planing and slotting, which is described very fully in the paper.

Clement had also various attachments to his machine for turning, milling, gear cutting and rack cutting. The writer thinks you will agree that Clement's planer was a most useful machine and did much towards advancing engineering work at that time. For ten years after it was set in motion it was the only machine of the sort available for planing large work, and being very much in request, it was often kept going day and night. This machine was in use as recently as about 1870, about which time all Clement's plant was sold at public auction.

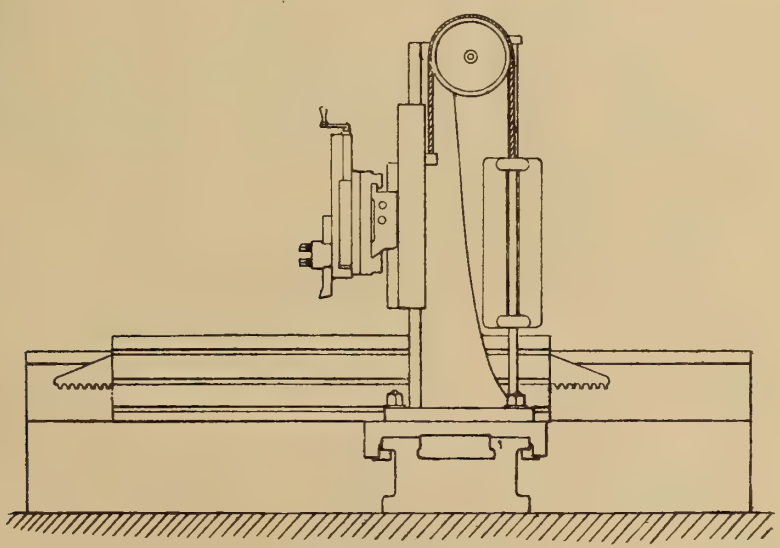
Following the sequence or order in

the appearance of the metal planing machines, we come next to that of Sir Joseph Whitworth, patented in 1835, at which time he was regularly manufacturing tools in Manchester.

It will be seen from this that the tool and the uprights were made to travel, instead of the table. There are good reasons why this plan is to be preferred for some kinds of work, and it would be interesting to have learned whether sufficient experience had been gained at that time to cause the "moving-tool" question to be considered as one of the "problems" of the time.



End Elevation.



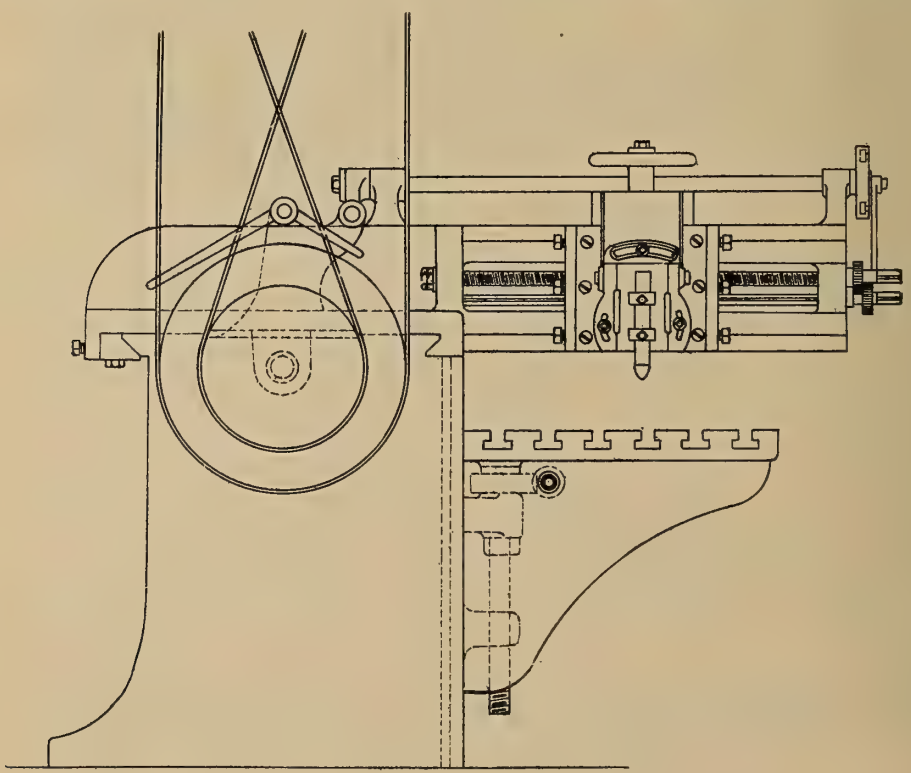
Side Elevation.

BODMER'S OPEN SIDE PLANER, 1839

The uprights, which are braced and tied to each other and carry the cross-slide, are mounted on wheels which travel along rails at each side of and below the table. The uprights are moved by two large, square-threaded screws, geared to rotate in unison, and to be automatically reversed. Instead of nuts for these screws to engage in, each upright carries two pairs of rollers, the axes of which lie obliquely, so that the threads of the screws engage the inner face of each roller on one side. Thus, two rollers on each side act to move the uprights in each direction. This method of driving by the double-screw and revolving discs was evidently one of Whitworth's mechanical hobbies at the time, as it is found in drawings of other machines in the 1835 patent. At the end of the stroke the tool was rotated by the famous "Jim Crow," so that a cut was taken in both directions. A feature of the feed is the reciprocating vertical rack now so commonly in use. The details of the framing of this machine are also instructive, as indicating the built-up practice at that time, when simplicity in moulding and casting were imperative, although not many years after the system of casting pieces as a whole and putting cores where needed was adopted.

Whitworth's machine hardly seems to indicate the knowledge of planing machines at that date, and not to have been along the line of development we should have expected, but more like an attempt to get out of the beaten track. This view is strengthened when we come to examine Roberts' machine, patented in 1838.

Probably the first planer built in America was that by the Silver &



HULSE'S OPEN SIDE PLANER, 1865

Gay Company, of North Chelmsford, Mass., about the year 1836. This machine had a capacity of 3½ feet square, and the table was driven by a heavy flat chain, very similar to modern sprocket chains. This planer had one V-way and one flat-way set on a bed of granite.

In Roberts' modern construction we see a machine of a much different type, containing many features of the present-day machines.

This drawing is valuable as showing the "state of the art" of such machines at the time, and must always remain of interest because of the advanced knowledge shown of the requirements in such machines.

Roberts, in his patent specification, says: "Having now particularly described my improvements in the machinery or apparatus for planing or cutting metals, and the manner in which the same is to be performed, I desire it to be understood that, although I have described in this, my specification, and shown in the drawings attached, many parts common to such machinery and hitherto in ordinary use, yet such has only been done for the sake of assisting the explanation of my invention; but I claim as my invention the use or employment of one or more cutting tools, with two or more cutting edges, to be used in planing machines, in the manner and for the purpose above particularly described."

From this it is evident that planing machines as shown in the drawing were the standard type at the time; but taken in conjunction with the drawings of Whitworth's planing machine in the 1835 patent and the planing machine of Clement of 1825, it represents a very rapid development of the planing machine between 1825 and 1838. No doubt we should give Roberts credit for having improved the planing machine on the lines shown in his drawings, and that his general disclaimer as to any novelty in the details and arrangement of his machine may be due to his difficulty in making a claim for it in his patent through having made it public and lost the privilege of claiming it. One will observe that his whole claim is in the method of planing in both directions of the stroke of the table by the tipping tools. It would be difficult to say how often this idea has been patented since.

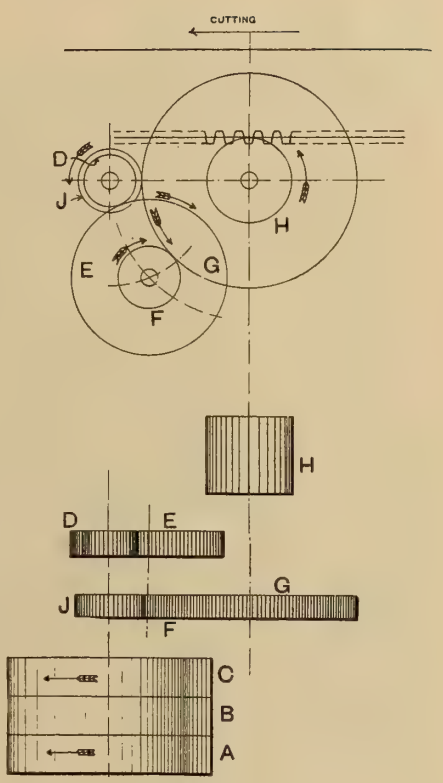
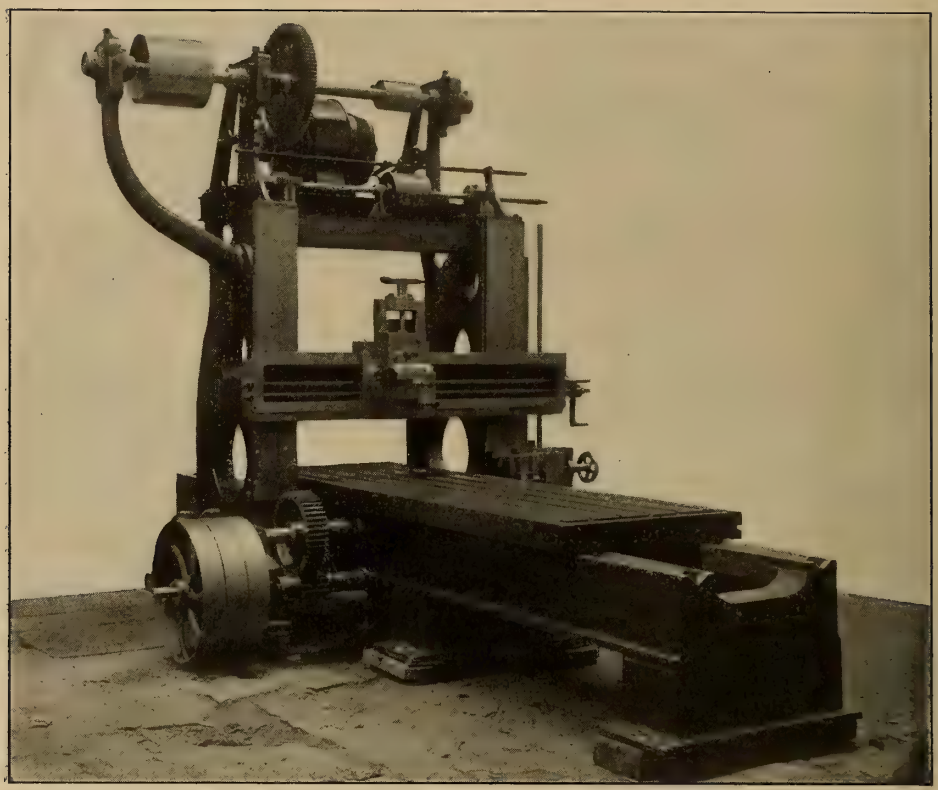


DIAGRAM OF OLD STYLE DRIVING ARRANGEMENT WITH SINGLE BELT

There are some of the details in the drawing of the Roberts planing machine which should attract attention, viz., the double pinion and stepped rack into which this works under the table. Roberts conceived, either from experience or pure reasoning, that a smoother motion would be given to the table by stepping the rack teeth and reducing the irregularities of the rack motion by one-half. It is a plan that, in the case of cast pinions and racks, gave good results, but is now almost entirely superseded by machine-cut gearing.



OLD STYLE DRIVING GEAR WITH ELECTRIC MOTOR

Roberts' planing machine, preserved in the South Kensington Museum, has the ways for the table arranged with a V on one side and a flat surface on the other. This is curious, as the system evidently died out, but has been revived in several machines, and has been regarded as a very important improvement in the guiding of tables, etc., as tending to produce more accurate results with only one guiding way instead of the two commonly used. Thus we see the evolution in practice.

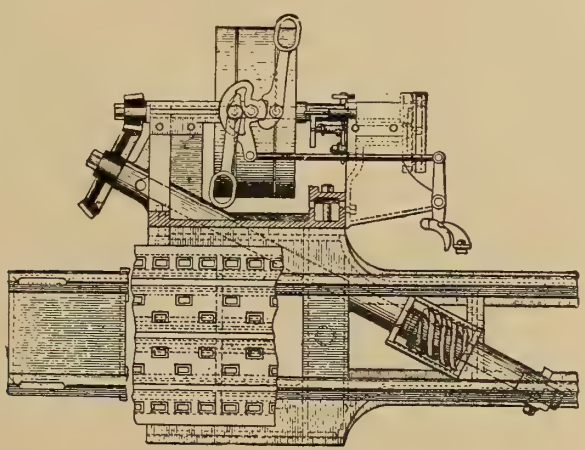
Most planing machines cut upon one stroke and idle their time upon the return stroke. When a machine has taken a stroke without doing any work, it unprofitably consumes time as well as power. The loss of time may be minimized by giving to the reciprocating table a very rapid return stroke; but the time so saved is saved at the expense of power, because in a reciprocating machine the power required to overcome the inertia of the reciprocating part, to arrest its motion, and impart fresh motion to it in an opposite direction is probably much greater than the power consumed in taking a cut. We have seen that the early engineers had all recognized the advantages of cutting on both strokes and arranged their tool-holders to suit. Whitworth's revolving tool box is still made. Our illustration shows a machine so fitted made in 1859, and still at work in their shops using high-speed steel. This tool box is made to turn through an angle of 180 degrees on each reversal of the table, so that it always presents the same cutting edge to the work. This form of tool box is almost universally used at the present day for plate edge planing machines, but it has many disadvantages for an ordi-

nary engineer's planing machine. It requires mechanism to turn it round. Although it presents the same edge it presents different corners to the work, and the tool requires, therefore, to be ground and fixed with great care. There are many jobs where there is not room for turning round the tool clear of the work at each end; in such cases the double cutting has to be abandoned, and there the fatal defect of this tool box becomes apparant, because the tool does not relieve itself, and being rigidly held with its back to the work, would have its edge rapidly rubbed off. This is probably the reason that this invention of Whitworth's has never been largely adopted, because it is essential that whatever form of double-cutting is used there should be the option of cutting in one direction only for such work as does not permit of any overrun of the tools. This tool box was nicknamed the "Jim Crow," owing to the alacrity with which it whisked round.

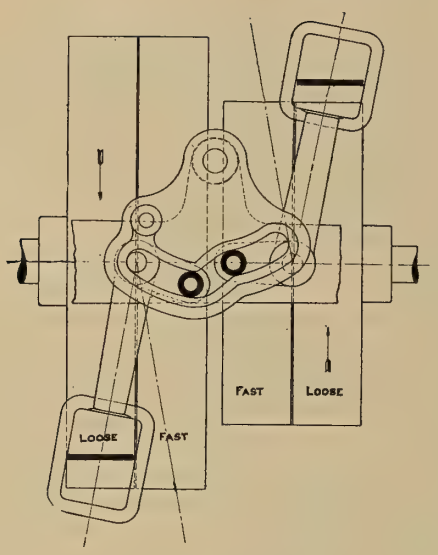
As can be imagined, there have been many attempts to obtain a satisfactory double-cutting tool box adapted for general use, and quite an evolution could be recorded of these; but space does not permit. Probably the most successful system has been invented by Mr. Wicksteed, of Joshua Buckton & Co., Ltd., Leeds. In this system two independent tools are used with the cutting faces back to back, either one of which will rock automatically whenever it comes in contact with uncut work. With this arrangement of holder there is only an idle run of the table required equal to the distance between the tools, which is about 6 inches, and cutting may take place at option on both strokes, or on either, according to the conditions of the work.

J. G. Bodmer was one of the most ingenious of mechanics of those days, and we can hardly leave these old masters without reference to some of his work. In 1839 he patented a machine, anticipating by many years the boring and turning mill, which he termed his "circular planing machine." It is interesting to notice that he had all the elements of the machine as known to-day, with a circular V-path for the table. Gearing was direct onto a small external wheel for high speeds and a large internal wheel for slow speeds. Further than this, he provided means to give a reciprocating motion to the table for planing small or awkward pieces of work.

The logical method of making a



SELLERS SPIRAL PINION DRIVING GEAR. PATENTED 1862



PIVOTED CAM BELT SHIFTER

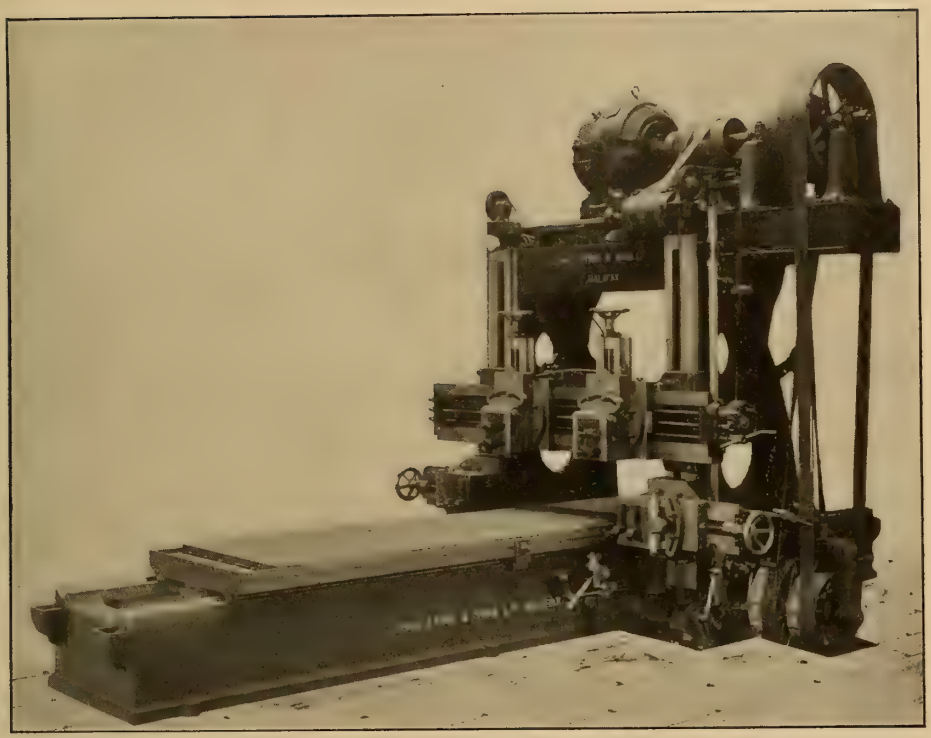
planer to get the greatest amount of rigidity to the tool slides and supports was to set up two vertical frames on each side of the table and put the cross-slide on the front of them. That this was correct theory is shown from its being the type that is universal to-day. But this form of machine is limited in taking in pieces that would pass between the uprights. This form of machine did not enable large and irregular pieces to be planed, and it became evident that other forms of machines were necessary to deal with these. Therefore, it is with interest that we now consider the type of planing machine shown in Bodmer's patent of 1839.

It is what is termed an open-side planer, and planes horizontal and vertical surfaces. The tool box at the end of the overhanging arm swivels to bring the tool to suit surfaces of any angle and shape, and the upright column also swivels on its base, so that an additional set of conditions are brought to bear on the application of the machine to pieces of almost any shape and size. The moving of heavy pieces, however, did not commend itself to engineers here, and instead of following Bodmer's type it was condemned as faulty in principle. The class of planing machines known as wall-planing machines, in which the tool has horizontal and vertical movement, while the piece of work is placed on the floor in front of it, has been considered more practical than moving the heavy pieces to be planed.

Here it is interesting to note the open-side planer, in which the work is fixed and the tool travels, patented by Hulse in 1865. The respective cut is taken from the patent drawing. In this same patent there were included other types of machines with traveling tools, and the description is so clearly put in the specification that we will take an extract from it:

"Instead of fixing the work to be planed on a traversing table, and employing stationary uprights, as hitherto adapted, I fix the work to a stationary bed or table and cause the uprights and cutter to traverse along it. The work to be planed is fixed to the bed or table, at the sides of which there are longitudinal slides extending the length of the bed, and in which are placed the lower parts of the upright, which are well stayed at the top and carry the cross-slide and one or more tool-holders. The uprights are propelled to and fro longitudinally by screws worked by pulleys and spur gearing, the pulleys being driven by open and cross straps, which are shifted as required by strap-forks worked by the moving uprights by means of inclined steps, which steps, as well as the self-acting motions for the vertical and transverse traverse of the tool, or tools, are worked in a similar manner in the ordinary planing machines. * * * By the improvements in planing machines which I have shown and described, I am enabled to economize space in the workshop and obtain great facility in placing the work upon and removing it from the machines."

From the wording of this specification, it appears as if Whitworth did not proceed with the development of his traveling upright machine, as



MODERN 5-FOOT PLANING MACHINE WITH TWO-BELT DRIVE AND SELF-CONTAINED ELECTRIC MOTOR.
JOHN STIKK & SONS, LTD., HALIFAX

those of Hulse came on the scene thirty years after, and the statement is made of "stationary uprights as hitherto adopted."

The wonderful saving in the cost of preparing flat surfaces effected by the first planing machines was such that it seemed to blunt improvement or refinement of the machine, which continued to be very much like the original models for many years. Then improvements began to be made, some of which, strange to say, have not even yet found their way into common practice, and the single-belt type of drive is still used to-day, generally on the cheaper class of machines sent abroad. We also illustrate a machine with this drive made during the present year and fitted with a self-contained motor-driven countershaft.

The system of driving planer tables by racks is one that has survived and is the most commonly used to-day. In the early machines a single driving belt was used, and the arrangement of the gearing was as shown in the illustration before the last one mentioned. Of the belt pulleys *A, B* and *C, A* is keyed on a shaft passing through the other pulleys and keyed to pinion *D; B* is a loose pulley turning freely on the shaft; *C* also runs loose on the shaft, but is secured to pinion *J*. The belt being on pulley *A,* the motion is transmitted through gears *D, E, F, G* and rack pinion *H* to the table. A slow-cutting traverse is thus obtained. At the end of the stroke the belt is moved from *A* to *C,* and then gear *G* is directly driven from *J*. As one pair of gears is thus dispensed with, two objects are effected: first, a reversal of the direction of motion of the table; second, a quicker rotation of *H,* and, therefore, a quick return

to the table. It should be noticed, however, that when *J* is driving, pinion *F*, being still in mesh with gear *G*, is driven round idly, and with it the gears *E* and *D*, this making one of the chief objections to this drive.

The first improvement made in this gearing was to substitute a larger diameter wheel to mesh into the rack, and pinion *H* meshed with this "bull wheel," as it is termed, instead of the rack. The effect of this is to give a very smooth motion to the table, because the wheel, on account of its size and arc of contact with the rack teeth, exerts a force that is almost constant and horizontal, and, therefore, has no lifting tendency, such as is unavoidable with small pinions. To effect the same purpose, one make of machine, the Kirchner, employs a steel wire rope instead of a rack, the rope passing around a drum attached to the bull wheel and to each end of the table. This was introduced in 1900.

Retracing our steps to the point where the improvements began, the other improvements consisted, first, in the employment of two driving belts instead of one; second, narrow driving belts moving at a high speed instead of wide ones at slow speed; third, differential shifting devices for the driving belts; and fourth, operating the feed motion from the driving gearing instead of from dogs on the table. These were the principal features. The exact date when the system of using two belts, open and crossed, was introduced in England is uncertain, but it must go back a long way, because in Hulse's 1865 patent the screws were driven "by crossed and open straps; but as

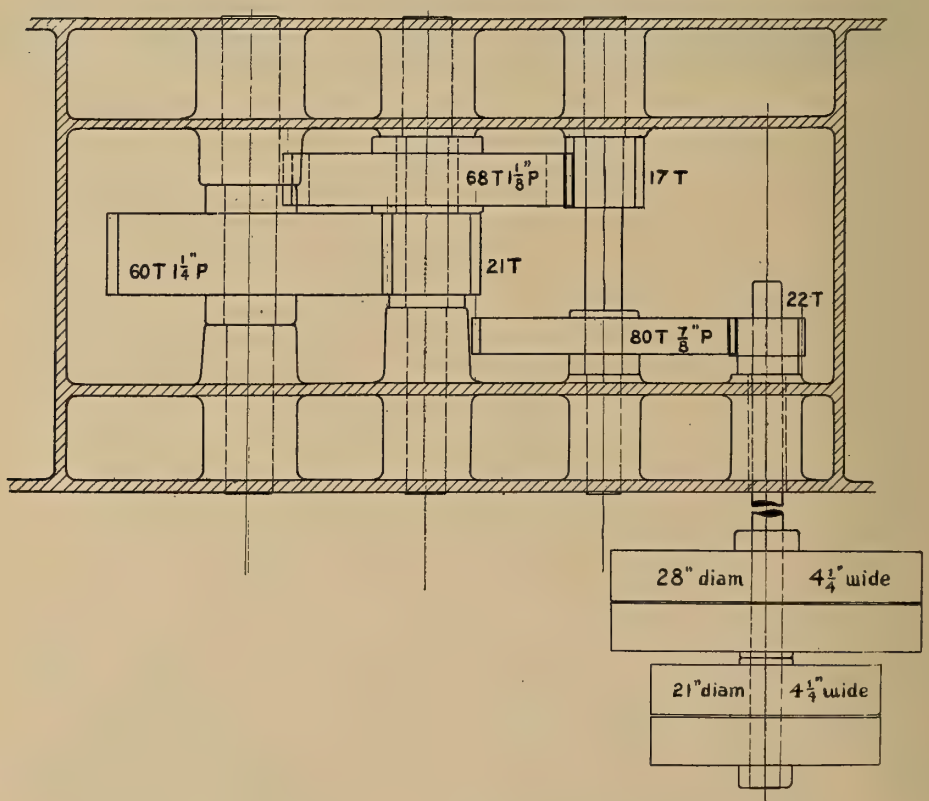


DIAGRAM OF GEARING ON PLANING MACHINE OF JOHN STIRK & SONS, LTD., HALIFAX

these contrivances were in ordinary use," he did not make any claim on them.

Previous to 1860 the firm of William Sellers & Co., of Philadelphia, Pa., U. S. A., made spur-geared, rack-driven planers which did not differ greatly from like machines made by other makers at the same time; but some time about 1860 Mr. William Sellers invented the spiral pinion drive and patented it in 1862. Our illustration is made from their original patent drawing, and shows pulleys for open and crossed belts and a cam belt-shifting device. In the spiral pinion drive the table rack is actuated by a short section of screw placed upon a shaft inclined at such an angle that the teeth on the table rack would properly engage with the threads of the screw. It was at first suggested that the rubbing action of the spiral pinion would tend to push the table toward one side or the other, in accordance with the direction of rotation of the pinion. Experiments showed that this effect was of no moment, and was further neutralized by giving to the teeth of the rack an inclination of 8 degrees. This drive is said to be the strongest and smoothest known, and the action of the threads on the rack is such that it is said to be almost frictionless and never wears out. In England the patent rights were obtained by Messrs. Sharp, Stewart & Co., of Manchester; Messrs. Joshua Buckton & Co., Ltd., of Leeds, are the principal users of this motion. It was used by them as early as 1876.

The use of two belts of narrow width running at high speeds in opposite directions was, perhaps, the most marked among the improvements, not only in permitting easy change and control of the speed for the forward-and-back motions of the table by altering the size of pulleys, but also in dispensing with an arrangement of noisy and perishable driving gearing, as with this method there are no idle gears. It also shortens the shifting range of the belts to one instead of two widths, laterally, and does not permit them to interfere and screech by both being in contact with the middle pulley at the same time.

The differential shifting gearing for the belts came in with the double belts, and was, of course, a sequence of that method of driving. By this mechanism one belt is always moved in advance of the other, and, as only one belt is handled at a time, it requires very little power to shift the belt. Fig. 13 shows a pivoted cam belt-shifter. When one bowl is working in the cam race the other bowl is riding stationary in a circular path.

To shift a belt from one pulley to another requires that it should be deflected edgewise, so as to wind in a spiral path across the faces of the pulleys; hence the ease with which a belt can be shifted is inversely as its width and directly as the time and velocity of movement.

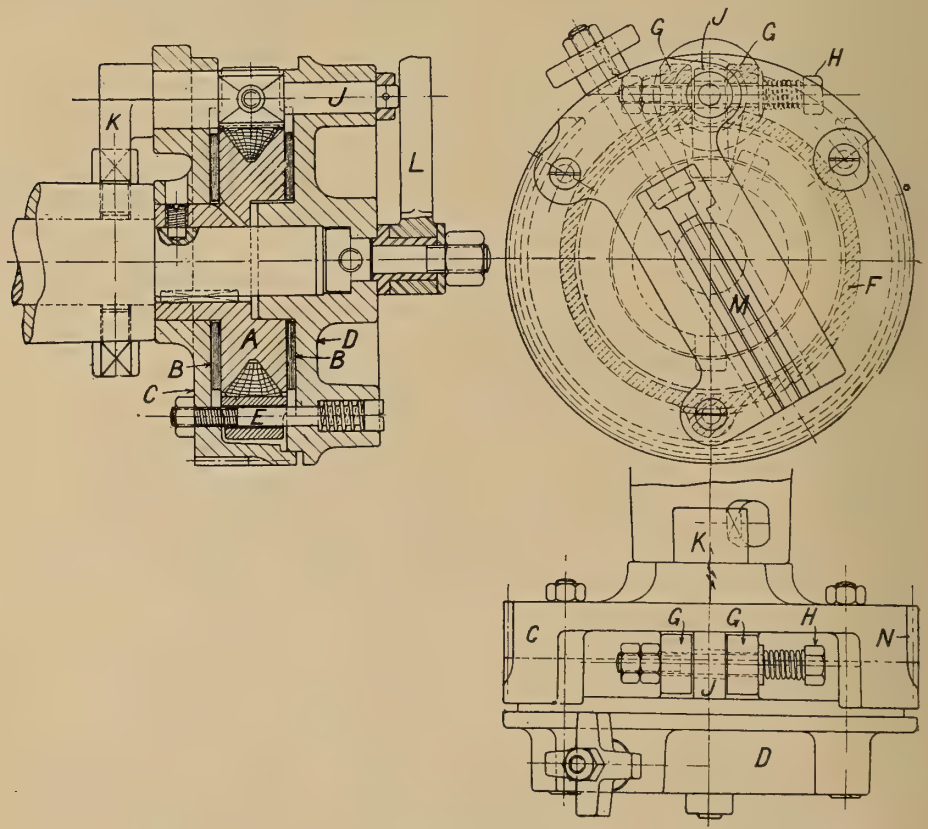
That the two-belt system is good practice is shown by the fact that it still retains its place in many high-class machines of moderate dimensions, up to 6 feet wide. A modern 5-foot machine so driven, which runs very satisfactorily at speeds of 40 feet per minute cutting and 100 feet per minute return, is made by Messrs. John Stirk & Sons, Ltd., of Halifax. The arrangement of the gearing is shown in Fig. 15, and is a good example of modern practice. The gearing is self-contained in the bed, and is all of forged steel, the wheels having steel rims and cast-iron centres, and a fine pitch of tooth is used throughout, the coarsest pitch—the rack—being 1¼ inches. Long bearings support the gears, which are thus held rigidly and free from vibration. The bed, too, at this point is of rigid construction, being of a box section.

The machine pulleys, which reverse, are of very light construction of steel; but the driving pulleys on the countershaft are made with heavy

rims, to give a fly-wheel effect to assist the belts and motor at the point of reversal. The countershaft is self-contained on the machine, and is motor-driven by an 18-horse-power motor, running at 420 revolutions per minute. The countershaft and armature shaft are supported on roller bearings, and very little power is expended in driving these. Running light, the power required to drive the machine, including motor and countershaft, was 2½ horse-power on the cutting stroke; reverse to quick return, 7½ horse-power; driving return stroke, 4¼ horse-power, and reverse to cutting stroke, 4¾ horse-power.

The belts run at high speeds; but not too high, as it is found that there is nothing gained by running the belts over 4,000 feet per minute. In this instance, it was sought to keep the rim speed of the largest pulley when running on the quick return in the neighbourhood of 5,000 feet per minute, so as to have a perfectly safe speed, and the pulleys and gearing were arranged with that object. The actual belt speeds are 1,980 and 3,510 feet per minute on the cutting and return strokes, respectively, and the highest rim speed is 4,700 feet per minute. This combination, with large-diameter driving pinions, gave a very smooth-running machine, prompt at reversal, without any shock or jar.

In referring to the improvements which had taken place, it was mentioned that one was the operating of the feed motion from the driving gearing. This has taken place in various ways, such as positive mo-



FRICTION FEED DISC

tions with clutch release after giving a turn to a feed disc, and fractional slipping devices. The feed motion is an intermittent one, and required to operate at the reversal of the machine. In the early forms a plain disc was used, with leather washers on either side compressed by springs. The disc was driven from the rack pinion shaft, and when this reversed the disc and the casing carrying the washers turned with it until they came against a fixed stop, when the motion was retarded until the next reversal.

The feed disc in the illustration is of an improved form and shown in detail by that cut. With this arrangement a greater turning effort can be imparted to the outer casing during the time required to put on the feed, and yet this effort can be released, when the casing is prevented from further rotation. The continually rotating disc *A* is keyed to the rack pinion shaft of the machine, and in its periphery is formed a V-groove. On either side of it are two leather washers *B B*, these being under pressure between *A* and the plates *C* and *D*, forming the outer casing, which are connected by three belts *E* fitted with springs, which force the plates towards each other. A friction band *F* encircles *A*, and this is provided with hard wood blocks, which fit the groove in *A*. It has also two projecting pieces *G G*, which pass through an opening in the upper part of the casing; by means of a belt *H* and spring, the band is closed upon the friction disc *A*. Between the projections *G G* is placed a stud *J* carried in bearings in the casing and having an outer arm *K* projecting towards the centre. This stud has two flat sides where it fits between the projections *G G*, and acts as a cam. It will be seen that if this stud *J* was twisted round slightly, it would have a tendency to force apart the projections *G G*. This is precisely what it does. As the whole case turns through the band *F* gripping *A*, the arm *K* strikes a fixed stop and prevents further movement of the case *C D*. The instant that the arm is engaged, the flattened portion of *J* forces open the friction band and prevents its gripping *A* again while the latter continues running in the same direction. When this direction is reversed at the end of the stroke, the band again grips *A* and the whole device turns until the arm meets another stop. The leather washers *B B* are pressed enough between the friction surfaces to ensure the arm being held against the stops with sufficient force to keep the friction band clear of *A*. They also assist the turning effect. In the sectional view the *F*-slot is shown out of projection for convenience. The connecting-rod *L* transmits the motion from the outer casing. The amount of motion is regulated by the distance of the connecting-rod pin from the centre, and this is adjusted by means of the screw *M*. The teeth cut in the casing at *N* transmit the motion to the side tool boxes.

(To be concluded.)

ELECTRIC HEATERS

By H. M. Phillips

ELECTRIC heating devices are rapidly growing in popularity, application now covers quite a wide field, and new uses are being found with surprising rapidity. During the past few years there have been many improvements in design, rendering the various contrivances more attractive in appearance, more convenient in operation and more durable in use. The economy has been improved in many cases, but probably not to such a marked extent as the features previously mentioned.

Little need be said here in regard to the convenience of these devices. It is self-evident, it is well advertised, it is frequently demonstrated for the benefit of the public. The central-station manager is a warm advocate of their use; his view of the subject may not be entirely disinterested, but our enthusiastic friends (who are not electricians) go the farthest of all and assure us that the time is close at hand when both gas and coal will be banished from the household. It may also be remarked that such devices are usually more sanitary than other methods of heating, that the danger of fire is in most cases less than when other methods are employed, that it is almost impossible to receive a shock during the ordinary operation of the apparatus, and that a shock which is in the least dangerous or even painful is almost if not absolutely impossible.

In most cases the cost of operating the various contrivances of this kind are lightly touched upon, the exception generally being the smaller pieces of apparatus. High operating cost, together with first cost and renewals, constitutes the chief drawback in regard to most classes of electric heaters.

If we can be sure that the apparatus will be reasonably long-lived, the fact that the first cost is apt to be rather high need hardly be considered here; the cost is easily ascertained, and we are willing to pay the price or we are not. Durability differs with the class of apparatus and with the manner of manufacture; purchasers of the cheapest grades are apt to be disappointed, although this is not necessarily the case; the extra cost may be warranted by the superior finish, lighter weight and more compact form of a certain make of heater, while durability may be sacrificed to obtain the latter points. In the majority of cases renewals or repairs are not of sufficient frequency to be a serious drawback; it is well to look into this part of the subject, however, when making a purchase, as some apparatus is manufactured in such a manner that ordinary repairs are not very expensive, while in other grades or makes the cost of same will be nearly equal to the first cost of the article; it may also be noted that the manufacturer is generally unwilling to make any very satisfactory guarantee in regard to durability.

An electric stove, of sufficient size, is exceedingly convenient for heating a small room when heat is only desired for a short time; it is, in most cases, rather an expensive method. The heater is, in nearly all cases, marked with the amount of current it consumes, from which the cost of operating may readily be obtained. Although the cost per hour is likely to be a rather small sum, the total at the end of a month is

likely to be larger than anticipated; the cost of continuous heating, especially for large rooms, would, in most cases, be prohibitive. A comparison of costs by different methods will serve to illustrate this very clearly; the gas heater will first be considered.

Any burner which does not allow gas to escape unconsumed—and this includes nearly all manufactured at the present time—will liberate a definite amount of heat when burning a fixed amount of gas of a given quality; the form and location of the heating device will determine, to a considerable extent, the manner in which the heat is distributed, upon which depends the bodily comfort of the occupant of the room. Five cubic feet of gas per hour may be burned in an ordinary open gas jet; it will not heat any room very satisfactorily, because nearly all the heat is carried to the ceiling by the strong current of very hot air that is found directly over the jet. If we stand quite near the jet we will immediately notice the warmth on the face, although the intervening air is very slightly affected. Heat made manifest in this manner is said to be radiated from the flame, and is somewhat of the same nature as sunlight; it will warm the surface on which it falls, but has little or no effect in warming the air through which it passes; one side of the body may be uncomfortably warm while the other is very cold. The radiated heat is in the present case a very small part of the total liberated by the burning gas. After the ceiling of the room has become warm the continued current of hot air rising from the flame will force some warm air down from the ceiling and the room may eventually become warm, the floor remaining cool till the last. A considerable amount of the heat will be lost, as far as usefulness is concerned, as the hot ceiling tends to heat the room above and the hot air near the ceiling has a strong tendency to escape through any possible outlet. If the gas jet is placed near the floor somewhat better results will be obtained; the current of hot air has farther to travel, and will mingle, to a certain extent, with the surrounding air; the radiant heat may also have a slight effect by warming the floor. The next step will be to burn the same amount of gas in one of the many good forms of gas stove; the actual amount of heat liberated will be no greater than before, but its distribution will be much more effectual. There will be a considerable amount of iron heated by the flame, and, in consequence, the current of air coming from the inside of the stove will have a considerably lower temperature than that over the open jet; moreover, it will probably be divided into a number of small streams as it issues from the stove. We have now, instead of a small column of very hot air passing rapidly to the ceiling, a number of jets which are not as hot as before and which mingle with the surrounding air; the tendency is still toward the ceiling, but the movement is not so rapid, and the column will be broken to a considerable extent by the slight draughts that are present in any inhabited room. There is also a large surface of iron which is heated to a moderate temperature. Generally speaking, the larger this surface is the lower will be the temperature and the better the results obtained. The iron heats the air with which it comes in contact, which also tends to rise, though not very rapidly; the iron also radiates heat which will tend to heat the floor, and, not falling upon the face, is rather pleasant for the occupant of the room. The burning gas robs the air of oxygen, the amount taken being the same in each case, although it may be more noticeable in the case of the stove, as the open jet sends nearly all of the vitiated air to the ceiling, where it will remain for a considerable length of time if it does not escape entirely. Considerable ventilation must be provided if the air is to be kept pure, and this means that cold air must enter and be

heated. If the stove is properly designed and kept clean, inside and out, there should be no odour; as it is somewhat difficult to keep the stove in this condition, they are apt to render the air unpleasant.

The unsanitary conditions produced by a gas stove may in some cases be remedied by connection to a chimney, in which case a portion of the heat is lost in the flue. If the draught is sufficient and the stove well designed, the purity of the air in the room will not suffer, may, in fact, be improved, as fresh air must be drawn in to take the place of that going up the chimney. The amount of heat wasted will depend almost entirely upon local conditions; but it seems fair to assume that double the amount of gas burned would at least heat the room as well as would a stove with no flue connection.

Actual amounts of heat are measured by the "British Thermal Unit" (abbreviated B. T. U.), which is the amount of heat required to raise the temperature of one pound of water one degree Fahrenheit. Heat and temperature should not be confused; the temperature of a burning match is very high, but it will not have much effect in heating a room; the temperature of a large hot-water radiator may be quite low, but it will heat the room. Five cubic feet of ordinary illuminating gas will liberate in being burned about 3,500 B. T. U.; that is to say, that if all of the heat produced could be utilized in heating water, none going to raise the temperature of the surrounding air or other substances, it would be capable of raising the temperature of 3,500 pounds of water one degree. The amount of electrical energy used is measured by the watt-hour; as in many cases this measurement would involve the use of rather large numbers, the kilowatt-hour is frequently substituted, its value being equal to 1,000 of the first unit. By multiplying the current taken by a piece of apparatus by the number of volts on the circuit (usually 110), we obtain the number of watts required to operate it; multiplying by the number of hours it is used, we obtain the watt-hours and dividing by 1,000 the kilowatt-hours (abbreviated KW. H.). The number of B. T. U. obtainable from five cubic feet of gas could only be stated approximately, as the quality of gas varies; the KW. H. does not vary, and is always capable of producing, or liberating, 3,412 B. T. U.; for purposes of comparison, we will assume that the KW. H. can supply the same number of B. T. U. as 5 cubic feet of gas, which in most cases would be favouring electricity.

The KW. H. represents sufficient power to burn eighteen ordinary 16-candle-power incandescent lamps for one hour, and such a number would have a considerable effect in heating a small room, much better than the single gas jet. There would be no strong current of hot air ascending to the ceiling, as the temperature of a lamp bulb is not high. The radiation, which was but a small part of the heat of the gas flame, constitutes a very large part of the total in the present case; if the lamps were placed close together, we would feel it very strongly on the parts of the body exposed to their light; if they were properly distributed, they would give, when standing in the proper location, a pleasant sensation of warmth to all parts of the body. This heat would be manifest the moment the lights were turned on, although the air of the room would remain cold for some time. The air of the room would only be heated indirectly; the walls, floor and other objects on which the light fell would be first warmed, and would, in turn, warm the air, which operation would necessarily be slow; some heat might also escape through the window. The lamps, or coils of wire, taking the same amount of current, may now be inclosed in a small metal box, or stove, and placed upon the floor. The heat from the lamps can no longer be radiated directly to the walls of the room or body of the occupant, but will be directly ex-

pended in heating the stove, which, if very small, might be raised to a temperature that would soften the glass in the lamps. If the stove be made larger, it will give out the same amount of heat as before, a constant amount being supplied by the current, but its temperature will be lower; with the same temperature the larger surface would give off more heat. The condition now is very similar to the gas stove; the hot iron heats the adjacent air, which ascends more or less rapidly to the ceiling; also, heat is radiated by the hot iron. No oxygen is taken from the air; there will be no odour unless the stove is very poorly designed and dirty. The electric stove consuming one KW. H. can hardly be more effective in heating the room than the gas stove burning 5 cubic feet of gas per hour without a flue connection, or 10 feet with a flue connection, it being assumed that each stove is of good design and operated for one hour. The electric stove cannot assist in the ventilation of the room, as does the gas stove with flue connection. The heat given out and gas consumed may be regulated at will in the case of the gas stove; some electric stoves have no heat regulation, and few have more than three heats at which they can be adjusted. With gas at $1 per thousand cubic feet and electricity at 10 cents per KW. H., the gas stove without flue connection would cost ½ cent per hour to operate, with flue connection 1 cent per hour; the electric stove would cost 10 cents per hour. Stoves of larger or smaller capacity would maintain the same ratio. An electrical heater of the above capacity operating on a 110-volt circuit would require a current of 9.1 amperes, which is more than should be taken from an ordinary lamp socket; 6 amperes is the most that should be taken from a lamp socket in any event, and even this amount is somewhat excessive and liable to overload the circuit to which the socket is connected. Additional wiring at very considerable expense may be required to heat a room by electricity. There are many forms of electric heaters, as there are of gas, more or less pleasing to the eye and effective in their distribution of heat; but none can depart from the fundamental principles noted above. Electric heaters for the above purpose should be very durable; some forms, however, are easily ruined by rust if left in a damp location, and in others the effort to save material and produce a cheap heater results in a construction subject to frequent electrical breakdowns.

We may now consider a steam, or hot water, radiator of sufficient size to supply the same amount of heat given in the previous cases. Except for the fact that the radiator is not portable, its heat should be at least as well distributed or effective in warming the room as in the other cases. Under favourable conditions it may be assumed that one-eighth of the heat is lost in transmission from the boiler to the radiator, in which case the boiler will have to give out 4,000 B. T. U. per hour to supply the radiator. A good quality of anthracite coal burned under a boiler of moderate size, such as may be found in a small factory or large apartment house or hotel, should furnish the boiler with approximately 8,000 B. T. U. for each pound burned; with such a boiler an additional one-half pound of coal would be burned to operate the heater for one hour. With coal at $5 per ton, this would cost ⅛ cent; the boiler used in an ordinary house will be much less efficient, and might run the cost up to ¼ cent. Of course, if steam were kept on the boiler for the purpose of supplying a single radiator of this size, and if the radiator were used but a short time each day, the cost would be enormously increased. The annoyance and expense of handling coal and ashes has not been considered, which form a more or less important item to be considered.

The same subject may be viewed in another light by considering a

building of sufficient size to operate its own electric plant. Coal is burned under a boiler which supplies steam, which drives an engine, which drives a dynamo furnishing the electricity which is to do the heating. The weak point in this chain of transmission is the engine. If steam were taken directly from the boiler for heating, and was used for no other purpose, nearly all of the heat given out by the boiler would be utilized in the radiators; there would be some loss of heat in carrying steam through the pipes, but this need hardly exceed 10 per cent. Now let the steam be used in the best available engines of large size, such as are found in the great power stations; fully 86 per cent. of the heat of the steam is thrown away once and for all; it cannot be recovered. The remaining 14 per cent. takes the form of power which the engine transmits to the dynamo, another 10 per cent. will be lost in the dynamo and wiring, leaving a possible 12.6 per cent. to be utilized by the electric heaters. In this case we have obtained about one-eighth the amount of heat that could have been utilized by the direct use of steam, burning the same amount of coal in each case. The ordinary plant is very much less efficient than this, and instead of one-eighth we would probably have about one-sixteenth; in addition, there is an expensive electric plant and the cost of operating same.

Water may be heated by electricity in a special vessel, such as an electric coffee pot; any ordinary vessel may be placed on an electric "hot plate." An electric heater is made which may be submerged in any vessel of sufficient size, and an "instantaneous heater" will furnish a small stream of hot water continuously. The minimum amount of power by which the desired result might be obtained is easily calculated; in some forms of apparatus the actual power will approach this result very closely, in others it may depart from it to almost any extent. One quart of water weighs about 2.08 pounds; to raise this to a temperature of 212 degrees (the boiling point) from a temperature of 45 degrees will require approximately $2.08 \times (212 - 45)$, or 348 B. T. U. It has already been stated that the KW. H. will develop 3,412 B. T. U.; consequently, with current at 10 cents per KW. H., the cost of heating this water cannot be less than $\frac{348 \times 10}{3{,}412}$, or 1.02 cents. Even though we double this amount, the cost is not very startling for a pot of coffee conveniently prepared; but a two-gallon dishpan full of hot water would amount to an appreciable sum; a hot bath would be quite an expensive luxury, although the water would not be heated to the boiling point and the cost would be in proportion to the number of degrees difference between the initial temperature and that required.

The number of amperes required depends to a considerable extent upon the rapidity with which the heating is done, and reaches a maximum with the instantaneous heater. Fifteen seconds to obtain a pint of water would seem a moderate flow in this case, but it would amount to 120 quarts per hour, which, with the same amount of heating previously assumed, would require 41,700 B. T. U. for an hour's use. 12.25 KW. H. would be required to do this work, which, at the former price, would cost $1.225, although the price per quart is the same as previously given. The number of amperes required at 110 volts would be $\frac{12{,}250}{110} = 111$. As this is the same whether the heater operates for 15 seconds or all day, it will be necessary in most cases to install expensive wiring to carry the current. The commercial instantaneous heater may not meet the conditions described above; if the flow of water is less, the number of amperes required will be de-

creased in the same proportion, which may slightly reduce the cost of wiring, but will have no effect on the cost per quart of heating. If the number of degrees of temperature through which the water is raised is decreased, both the current and the cost of heating may be reduced. Unless some special regulating device is provided, this heater furnishes a constant amount of heat; therefore, a difference of temperature in the cold water supply will cause a like difference in the hot water. If for any reason the water runs more rapidly at one time than another, the temperature will be correspondingly lowered. There is no power used when the faucet is not turned on, as turning off the water shuts off the current; a failure of the water supply would, however, cause the current to damage or destroy the apparatus if the faucet were left open unless some safety device guarding against this is provided. It would evidently be bad policy to leave the water running over night with this apparatus.

We might assume that the coffee heater or similar device is so carefully covered with some material that is a non-conductor of heat (lagged would be the technical term) that no heat escaped to the surrounding air; then, neglecting the small amount of heat required to warm the interior parts of the vessel, 348 B. T. U. would be required to raise a quart of water from 45 degrees to the boiling point, at a cost of 1.02 cents. It would make no difference, except in the time required for heating, whether the necessary heat units were applied slowly or rapidly. At 110 volts 9.3 amperes would heat the water in six minutes; .93 amperes would produce the same result at the same cost in one hour. Of course, it would be impossible to obtain such results in practice, and no attempt is made to approach it very closely. More or less "lagging" may be used, but a thick covering applied to small articles would not only increase the expense, but would also make them clumsy. If sufficient current were used to raise the temperature quickly, boiling might be too violent after 212 degrees were attained; moreover, the apparatus would overheat to a dangerous extent if current were left on when it was empty. With the present commercial apparatus it is safe to say that .93 amperes would never bring the water to the boiling point; the heating would be very slow, and at some point considerably below 212 degrees the outside of the vessel would dissipate heat into the air as rapidly as it was supplied by the current, no further rise of temperature being attained. An increase in the amount of current would cause the liquid to heat more rapidly, and the ultimate temperature would be raised. When sufficient current is used to finally reach the boiling point a further increase will cause that point to be reached more quickly and to increase the rapidity of the boiling if the current is left on. With the smaller currents no harm should result if heat was left on with the vessel empty; commercial heaters may be manufactured which will stand this treatment without injury, but it is safer not to try the experiment. Large currents tend toward economy in heating, if they are not left on after the proper temperature is reached; the operation being quicker, less heat is given to the air; if their use is continued for a longer period, they are obviously more expensive. Heat-regulating devices might, of course, be supplied; but it is not customary to do so with the smaller forms of apparatus.

It would be difficult to make a comparison between the cost of heating by the above method and by gas, as both are subject to wide variations in the efficiency of application. There can be little doubt that in nearly all cases much more heat is wasted by the use of gas than by electricity. In spite of this, from the minimum cost first given it is apparent that gas is the cheaper fuel. A comparison with

heating by submerged steam coils, such as are used in large heaters, is easily made; it is the same as that of the steam radiator and electric stove for heating a room. If the piping is so poorly arranged that there is a large loss outside of the heater, such loss must be considered. No definite statement can be made in regard to the life of electric apparatus of the nature described; there is no doubt that it could be so made that it would last almost indefinitely. Such construction might be expensive, and would probably tend to make the heater heavy and cumbersome; an attempt to make it as light as possible and at very low cost would result in an extremely short life. The commercial product may lie anywhere between these extremes.

Electric flatirons have many advantages; they may be used continuously without loss of time in changing irons, and, if properly constructed and handled, will keep a temperature that is nearly constant; they are also rather expensive current consumers. No minimum cost can be figured, as has been done in the preceding case; but it can be shown that an attempt to materially increase the efficiency of the present forms will result in unsatisfactory service. If the iron were to be operated continuously and at a fixed speed on work of one character only, it would be so designed as to approach maximum efficiency. It would be so lagged that there would be very little heat given off except at the working surface, and just the proper amount of electrical energy, or B. T. U., would be supplied to do the necessary work of heating and drying the cloth. This iron, or the working parts of same, would be made as light as possible, in order that when current was turned on there would not be much metal to heat, in consequence of which the working temperature would be quickly attained. If more weight were needed to press the cloth, it would be added to the first unit; it would be outside the lagging and would not be heated. If the work were very damp and the iron moved at a comparatively high speed, quite a large amount of heat would be required to dry out the cloth and do the work properly; this would fix the amount of current required by the iron. A change to work that is not so damp or a slower movement would result in a rapid increase of temperature, the same amount of heat being supplied to the iron but less taken away by the work. A constant temperature would be reached when the work was heated to a sufficient extent to again take all the heat furnished by the current. It is quite likely that the cloth would be scorched before this point was reached; it would be sure to be, if the iron were allowed to stand on the work for a short time. When these changes in the character of the work or the speed of the iron are of brief duration, they may be partially overcome by adding to the amount of metal which is heated by the current. The temperature will now rise more slowly, for the same reason that a large iron takes longer to heat than a small one. The increase will not be great enough to damage the fabric, and the iron will gradually return to its former temperature when used on the work first considered. The iron now takes longer to heat before starting work, and a desirable feature is lost to the extent necessary to produce the desired result in regulating temperature. Although the method just considered will be effective for a short time, it is obvious that it will be of no use if the change in the work is of sufficiently long duration; the rise will be less rapid, but the final temperature attained will be the same. The next step will be to remove a portion of the lagging. The surrounding air is now heated to a considerable extent when the iron is working under normal conditions, and the current supplied must be sufficiently increased to make up for the loss; the iron will cost more to operate. With the same change in the character of the work as before

the temperature will again rise, but in this case the amount of heat given to the air will increase with the heat of the iron; consequently, the maximum temperature obtainable, when heat is given out as rapidly as it is supplied, will be lower than before, and may remain within the safe limit.

The commercial iron must be a compromise between the conflicting conditions just described; when the work is wet or necessitates a high temperature, it will be necessary to operate the iron rather slowly; in other cases the iron may be somewhat warmer than is desirable. It is pretty sure to scorch fabric or wood if left standing on same for any length of time, and might become too hot for use if left on an asbestos pad; for this reason the iron should be provided with a metal stand, on which it should be placed when not in use; the temperature will then increase to some extent, but the metal takes the heat away with sufficient rapidity to prevent excessive heating. Some lagging is generally provided, but if too much is used it will tend to produce undesirable changes in the temperature of the iron. Different manufacturers will meet the above conditions in different ways, and will use different amounts of current to operate their irons. A 6-pound iron should take somewhere in the vicinity of 3.5 amperes to operate on a 110-volt circuit; one hour's use of the iron would require .385 KW. H., and with power at 10 cents per KW. H., would cost 3.85 cents per hour to operate. The cost of heating irons by gas for a single operator should not be much in excess of one-half cent per hour. The heat from a gas stove is apt to be objectionable, although the iron itself may be so lagged as to waste no more heat while in use than the electric one. The fact that it is necessary to change irons quite frequently is partially balanced by the ability to use a very hot or comparatively cool iron as desired. Heat-regulating devices might readily be used in connection with the electric iron; but as it would add to the expense and might be mishandled, this is not usually done. The freedom from breakdown depends very largely upon the method of manufacture, but in most cases very satisfactory results may be expected. In spite of the apparent drawbacks to its use, the electric iron is used to a considerable extent by progressive laundrymen; they find that it pays.

Various forms of cooking utensils follow the general lines already laid down; their chief attraction is their convenience, cleanliness and small amount of external heat. Such efficiency as they have, lies in the fact that they concentrate their heat where it is needed; but, as a rule, the expense for current is considerably greater than would be incurred in operating by gas or coal. The temperature of the apparatus is subject to wide variations with the character of the work it is doing unless regulating devices are provided, which is done with the larger pieces of apparatus; and an attempt to improve the electrical efficiency is likely to increase the fluctuations in temperature.

Electric soldering irons are exceedingly convenient, especially in the smaller sizes; the current used will depend upon the size of the iron. The principles governing their efficiency are nearly the same as with the electric flatiron. In spite of the fact that, owing to their high temperature and small size, their deterioration is quite rapid, they are found to be a paying investment by some large manufacturing establishments that keep them in almost continuous use. Where they are used only occasionally, the fact that they do away with a fire and can be attached to almost any lamp socket makes their value still more marked.

Where extremely high temperatures are desired, the electric furnace is capable of doing work beyond the range of any other heating device.

THE CABLEWAY AND ITS USES

By Sterling H. Bunnell

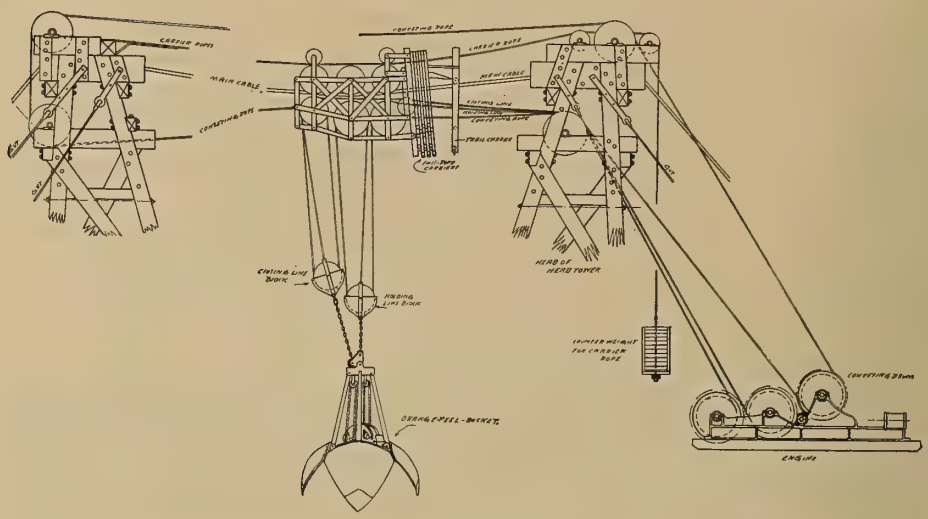
FOR most contractors' operations requiring the transportation of material over moderate distances, the suspended cable, with traveling, hoisting and propelling lines and suitable bucket, possesses many advantages over wagons and railway cars. The main cable, supported high in the air over its terminal towers, provides a roadway independent of obstructions and of the conformation of the ground. It may cross a gorge, valley, stream or railway with its clear span, depending on no support except at either end of the cableway. It does not interfere with the passage of wagons, trains or boats below the cable, so that the work can be carried on simultaneously at several points in the line. Its single engine is controlled by one man, who may carry on the whole work of loading, transporting and dumping in many cases without the aid of other men.

By means of the cableway, with suitable equipment in the way of engines, sheaves, carriers and bucket or skip, almost any kind of hoisting and transporting may be carried on with economy and speed. The limit of span is near 2,500 feet. The carriage being secured to an endless line which absolutely governs its movement, may travel at a very high speed if desired—1,800 feet per minute or even more—and the load lifted and conveyed may be up to 20 tons on moderate spans. The work performed, in the simplest form, is the lifting of a bucket or skip, previously filled by labourers with shovels, and traversing the load along the cableway to the end, where the carrier is dumped by another man. This system is used for trenching, the cableway being set up over and in line with the ditch. The material from the excavation is carried back along the line and dumped to back-fill the trench. The whole cableway is moved forward from time to time as the work proceeds. A small cableway of this character costs but little, and greatly facilitates ordinary trenching operations, as for pipe-laying in city streets. At the other extreme are the heavy cableways used for wide excavations, the operations performed being the dragging of a huge, self-loading scraper-bucket, the hoisting of this bucket when filled, and its transportation and final dumping near the end of the cableway on the spoil bank raised at one side of the excavation. The cableway here comes into direct and successful competition with the heavy boom-derrick, doing the same work with a substantial saving in first cost of apparatus and certainly no disadvantage in operating expense.

The variety of uses for the cableway is already very great, and the field is by no means exhausted. From simple back-filling of a small trench it was an easy step to using the same hoisting machinery to lower pipes, bricks, mortar or concrete into the excavation. Retaining walls and

CABLEWAY BUILT BY THE LIDGERWOOD MFG. CO., NEW YORK, FOR CONSTRUCTION OF THE BARKER DAM, NEAR BOULDER, COL.

foundations are rapidly constructed by the aid of an overhead cable, along which the materials are delivered to the workmen. A wide field is open in those cases where the work is inaccessible along the ground, as in filling across a precipitous gorge in railway construction, or constructing a concrete bridge across a river. Dams are built across streams either by dumping loose material under the cableway or by conveying and delivering concrete from a mixer on one of the banks. Logs are hauled from booms by cableways stretched across the river. Blocks of stone and marble are run up incline cableways from quarries, thus performing with a single cableway work that would otherwise require both a derrick and a railway track. Lumber, steel plates and beams and other heavy articles may be cheaply and quickly moved, piled or loaded on cars. By the use of well-known forms of automatic buckets the cableway picks up its own load. Clamshell and orange-peel buckets serve to load or unload sand, coke, coal and all other loose materials from or into boats, stock-piles or bins. Dredging of channels, excavating for docks and similar operations are carried on from solid ground with economy and speed. Suitable heavy excavating buckets or dredges perform work formerly pos-



DUPLEX ROPE CARRIER SYSTEM WITH ORANGE-PEEL BUCKET. NEW YORK CABLEWAY & ENGINEERING CO., NEW YORK

sible to nothing but the steam-shovel. The scraper-bucket is suited to the hardest soil, even when stones and small bowlders are present. A heavy drag-line, operated by a powerfully-geared drum turning at slow speed, tows the bucket along the cableway, the steel cutting edge shaving off a layer of earth, which rolls up on itself in the bucket. When the scraper is full, the bucket is hoisted, propelled along the cableway, and dumped at any desired point. The cable for such operations is stretched transversely to the excavation, as in digging a canal, and the scraper works from the center towards the side of the channel, dragging up the bank as it fills.

In many contracts for excavation it is impossible to know accurately in advance the character of all of the subsoil that may be formed. On other jobs it is known that large quantities of several kinds of gravel, earth, stones and broken rock will be encountered. A proper cableway equipment for such excavations is adapted to work equally well with all forms of bucket, and is thus readily adjusted to the requirements of whatever conditions may be found. The same engine and lines may be connected to clamshell or orange-peel buckets or skips of various forms, and these may be readily exchanged one for the other as desired. In deep excavations this adaptability of the cableway is of great importance.

The design of a cableway suited to any special requirement requires experience and good judgment. The construction involves only simple parts and details, readily obtained in the open market. The main cable forming the roadway is of steel wires. As great flexibility is not essential, this line may be of flattened strand, Lang-lay or locked-wire rope, giving greater wearing surface than the regular twisted-strand ropes. The extra first cost is a good investment. The main cable passes over terminal towers and is secured to "dead-men" buried in the ground, or to heavy anchorages of stone or concrete. Tackle-blocks and rope provide means for straining the main cable into position, or long turn-buckles may be used on light cableways. The usual sag, allowed for the main cable with full load suspended at its centre, is about 5 per cent. of the span, the resulting strain on the main cable being five times

the weight of carriage and load plus two and one-half times the weight of the suspended cables between the towers. If the proportions of load and span permit, the sag can be reduced, if preferred, to allow of correspondingly reducing the height of towers. Since the strain on the anchorage connections is heavy, and failure of the support very dangerous, the dead-man or other form of attachment should be most carefully placed. A heavy log may be buried in a T-shaped trench in the ground, the log forming the crosspiece and the attached main cable the shank. This arrangement leaves the ends of the log resting against materials and undisturbed ground. The dead-man may be buried in a mass of concrete, if the construction is to be permanent, or attached to a massive anchorage of masonry or concrete, with steel rails or beams embedded to distribute the strain of the cable. On permanent work it is wise to connect the guys to anchorages separate from the main cable, so that failure of the one need not affect the other. The towers would thus be saved even though the main cable should break away.

The supporting towers are usually of wood for temporary cableways and steel for permanent work, or where wood cannot be had. A frame wood tower is commonly used for trenching apparatus, with one back and one or two front guys for each tower. For tall towers the main timbers must be spliced and trussed. More substantial towers have four posts and one guy at the rear to take the strain of the main cable. Towers may be built in the field of logs or rough timber, the bolts and irons being shipped to the required point ready for use. Steel frame towers for permanent work are designed like other structures, shipped in sections and put together in place with rods or bolts.

Where the cableway is to be moved as the work progresses, the towers may be provided with wheels and a suitable track laid for their support. The trucks may be parallel, or one tower may be stationary and the other movable on a circular track, or both towers may be arranged on opposite sides of a circular track, as for working over a circular storage pile for coal, coke or sand. With the radical arrangement, it is most important to locate the stationary tower at the exact centre of the circular ore or

DUMPING BRIDGE ON 80-FOOT FILL AT BLAIRSTOWN, N. J. BUILT BY THE NEW YORK CABLEWAY & ENGINEERING CO., NEW YORK

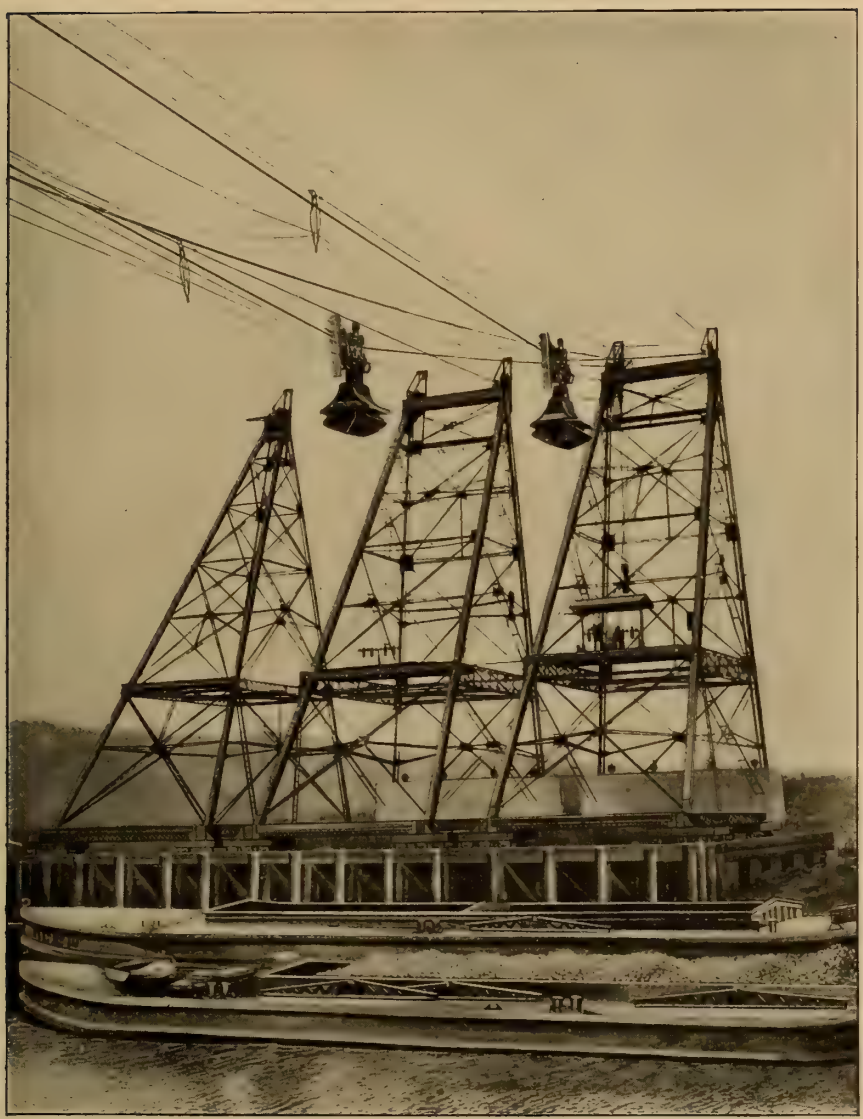
circumference, or the cableway may be wrecked by excessive tension due to eccentric movement of the rolling tower.

Movable towers must be counterweighted, or the guys must be shifted from one attaching point to another, or adjusted in length. The moving is performed by tackle-blocks and line, using the main hoisting engine for power. If convenient, the tail of the fall used for moving the tower may be hitched to the hoisting-block and the hoisting drum operated to move the tower along. Permanent cableways have endless chains and separate engines, or locomotive construction under the towers similar to steam-shovels. The applications of movable-tower cableways have thus far covered only a small part of the possible field.

The cableway with traveling towers performs all the functions of the traveling crane without the same limitations of span length. With permanent steel towers of locomotive type on parallel tracks, or connected by a track cable overhauled by an engine, coal-storage plants may be equipped at much less cost than with heavy steel bridges. Similar equipments of low cost are suitable for handling sand or broken stone in immense quantities. A fan-shaped or semi-circular stock-pile, reached by a cableway with one stationary tower on the water front, so constructed as to allow the carriage to travel out over the edge of the wharf, effects the unloading of scows and barges with very great economy.

HIGH-SPEED, GRAB-BUCKET CABLEWAYS AT THE GATUN LOCKS, PANAMA CANAL. LIDGERWOOD MFG. CO., NEW YORK

The traveling carriage of the cableway is a simple frame of steel bars carrying two sheaves running on the main cable and other sheaves over which the hoisting rope runs. Telpherage systems require carriages with framing on one side of the rope only, so that the carriage may pass the towers supporting the main cable at intervals. The term "cableway" is



LIDGERWOOD CABLEWAYS AT GATUN LOCKS. CARRIAGE SPEED 2,500 FEET PER MINUTE

properly limited to constructions having but one span of cable on which the travel of the carriage is necessarily limited to the space between the towers. The sheaves in the lower part of the carriage perform the functions of the upper block of a tackle, and the hoisting line, or lines, may be single and directly attached to the bucket, or make any number of turns about blocks to reduce the strain on the lines. As lubrication is likely to be neglected, the carriage should be provided with hard steel axles and good anti-friction bushings for its sheaves. The carriage is attached at either end to the corresponding end of the traversing line, which thus forms an endless rope. This rope makes several turns around one of the drums of the reversing engine which operates the cableway,

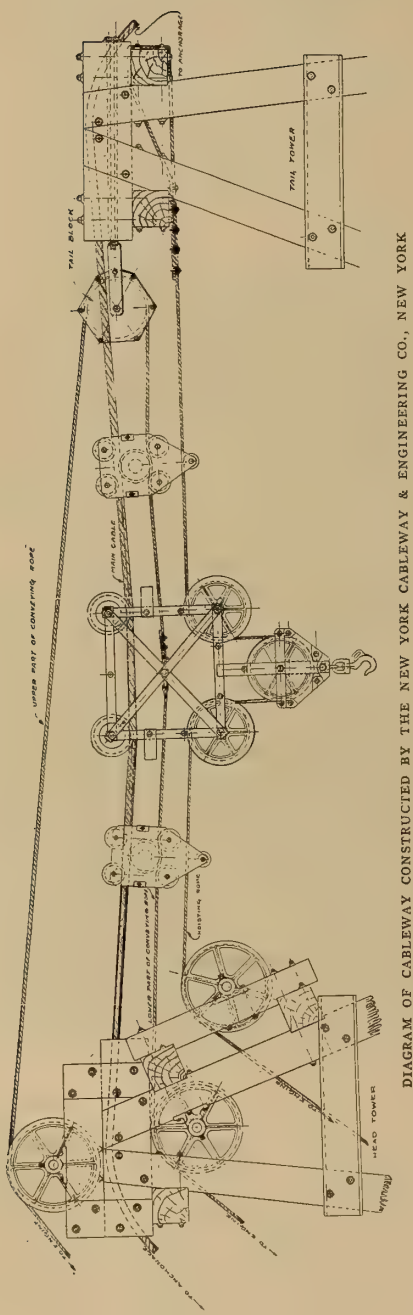
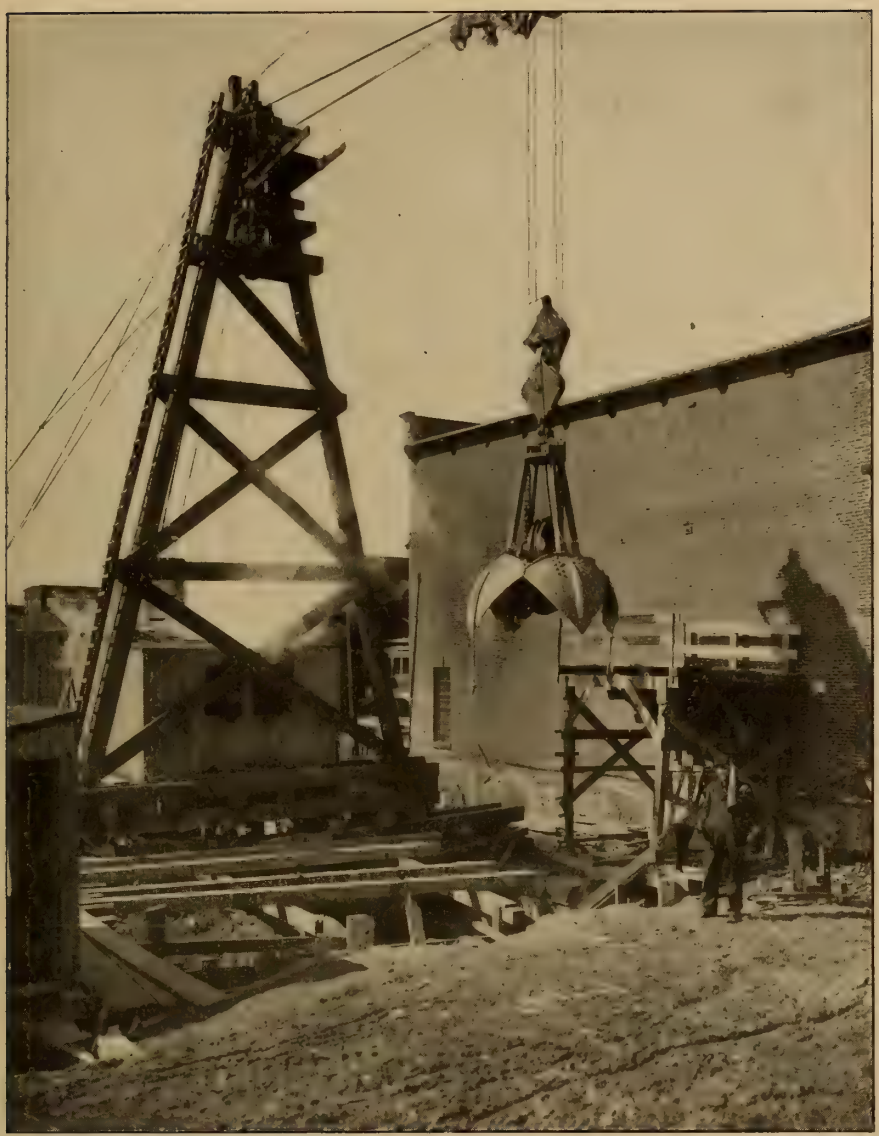


DIAGRAM OF CABLEWAY CONSTRUCTED BY THE NEW YORK CABLEWAY & ENGINEERING CO., NEW YORK

and by its means the carriage is pulled either way along the main cable.

The hoisting rope presents the most difficult problem of the cableway. The strain upon it, and, therefore, the sag of the span, varies with the loading or unloading of the bucket. In very short cableways for light work a single hoisting line may be led from the engine around a sheave in the top of the adjacent tower over to the carriage and down over a sheave to the bucket. Enough permanent weight on the bucket, or bucket tackle block, is supplied to keep the hoisting rope up off the ground. With this arrangement the hoisting rope must be wound or unwound with the traversing rope to maintain the height of the bucket. The out-haul end of the traversing rope must also support a strain equal to that in the hoisting line in addition to its own initial tension. This strain is generally taken off the traversing rope by carrying the hoisting line up around a sheave in the bucket block, over a second sheave in the carriage, and on to the tower opposite the engine, in the manner well known in crane practice. This permits of hoisting or lowering the bucket simultaneously with traversing the carriage. The varying strain of the load upon the hoisting line, with the varying sag resulting, is counteracted in one of several ways, as follows:

The most usual method is to hold up the horizontal part of the hoisting rope by a series of idler pulleys in carriers running on a main cable. These are spaced behind the carriage as it travels along the main cable. One method of spacing them is by connecting them at equal distances along a chain. The tendency of the slack chains to foul each other, and the heavy strain on the traversing rope as they are stretched out behind the advancing carriage, limit the use of this system to slow speeds. Another method provides an extra wire rope carrying knobs or



CABLEWAY TOWER AND ORANGE-PEEL BUCKET. NEW YORK CABLEWAY & ENGINEERING CO., NEW YORK

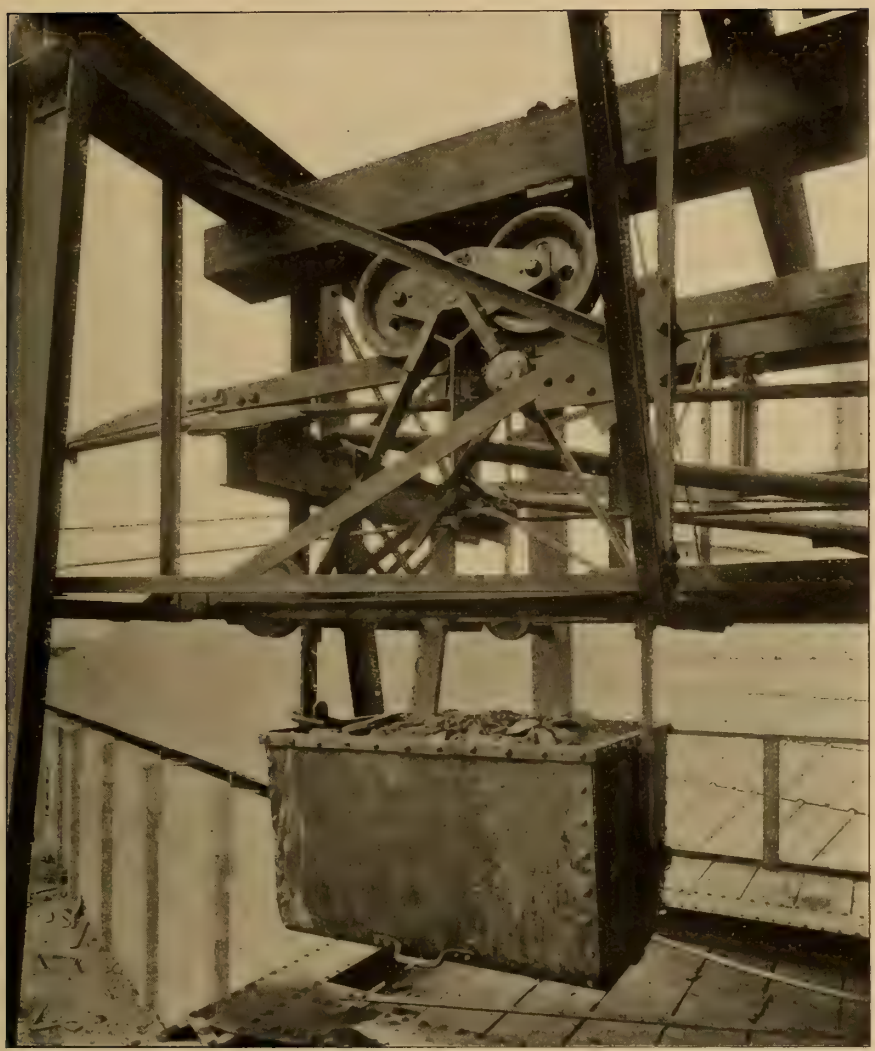
bosses attached at intervals, known as the button-rope. The carriers ride on a steel horn projecting from the end of the carriage, and embrace the button rope by jaws or loops of varying width. The buttons are made of regularly increasing size from the tower out along the span. The first carrier to be dropped has the narrowest slot, and is caught by the smallest button, which has passed through the wide jaw of the other carriers without interference. In this way each carrier is taken off by the button corresponding, and the hoisting rope is held up at equal distances by suitable sheaves provided in the carriers.

In order to avoid the striking of the buttons by the carriers the pat-

DEVICE FOR ATTACHING THE BUCKETS TO THE CABLE AT THE TERMINALS. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

ented differential rope system of spacing has been devised. The button-rope is replaced by two smaller lines, suspended side by side and spreading like the sides of a wedge, being held apart by suitable graduated blocks fastened between the ropes. The carriers are partly supported by long rollers resting on both ropes. As the carriage runs out from the tower, the diverging differential ropes pick each carrier successively off the carriage without the slightest shock. This affords a smooth-running carrier system suited to the highest speeds and essentially free from accident.

Another system employs trolley carriers running on the main cable and propelled by the traversing rope, so that they proceed at some definite fraction of the speed of traverse. The simplest is the half-speed carrier, in which a single sheave in contact with the main cable sheave and with the traversing rope below propels the carrier frame so that it supports the hoisting rope at a point always midway between tower and carriage. This reduction of the un-



DEVICE FOR DETACHING THE BUCKETS FROM CABLE AT THE TERMINALS. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

supported span to one-half is sufficient for the successful operation of most cableways, though similar traveling carriages geared to one-fourth and three-fourths speed have been used for unusually long spans. Slippage, if it should occur, causes no trouble, as the carriers are forced together by the main carriage whenever it approaches close to the tower, and are thus brought back occasionally to a common starting point.

Still another system of sustaining the hoisting rope is in occasional use. In this there is provided an endless hoisting line, strained initially to support itself with the same sag as the main cable. At a point on this line there is attached the end of the fall-rope which supports the bucket from the carriage. By advancing the endless hoisting line and holding back on the endless traversing rope, the fall-rope is drawn out and the bucket hoisted. There are at least two objections to this system. The load

VIEW ALONG CABLEWAY LINE, SHOWING TOWER AND PROTECTING BRIDGE. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

cannot be hoisted close to the tail tower, for the branch rope leading to the fall blocks would foul with the tower sheaves. With a three or four-part line and a high lift, this fault prevents the use of a large portion of the cableway. The wear on the hoisting line is as great as on the traversing line, since both must slide across their spool drums as they are overhauled, and any attempt at high speed will cause the endless hoisting line and branch fall-rope to twist up and foul.

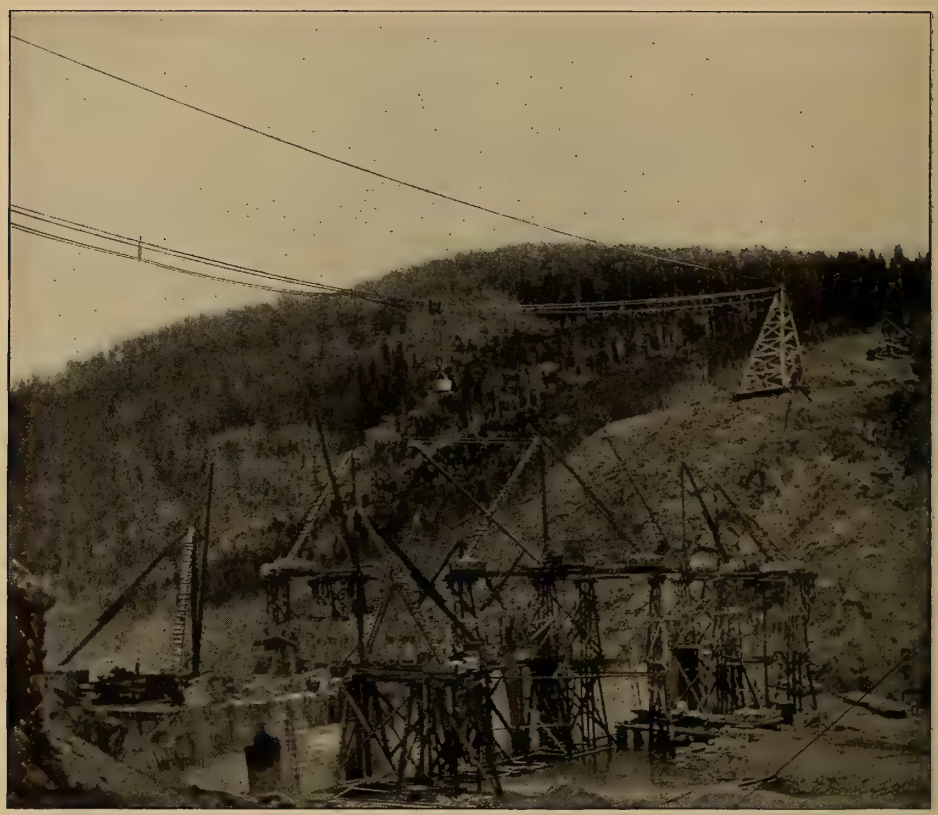
With a single hoisting line, the only practicable form of bucket is a single skip or tub, filled by hand, and dumped by unlatching it and allowing it to turn over, or by lowering it onto inclines that tilt it so as to let the contents slide out, or by setting it down until the chains supporting one end can be unhooked, either by a man or automatically, and then

hoisting again so as to empty it. For rapid excavation, dredging or unloading, self-filling and self-dumping buckets with two hoisting lines are required. One of these lines may lift and the other close an orange-peel or clamshell bucket; or one may be attached to each end of a skip, whose contents are dumped by hauling up one end or letting down the other. The two lines must be wound up together and at the same speed for hoisting, or separately actuated for filling and dumping, so that the manner of operating them in connection with the engine is of much interest.

It is evident that a skip may be dumped either by lowering the open end or by raising the other end. This may be accomplished by winding both lines on a single drum, with special accessories. To dump by lowering one end of the skip, the hoisting drum is stopped after the load has been raised, the dumping line is clamped by a steam-power brake, and the drum is allowed to run down until the skip is inclined sufficiently. The dumping line between brake and drum slackens during this progress, and tends to pile up upon itself when the drum is again started forward, which damages the wire rope by bending and crushing where the coils cross. To dump by raising the back of the skip, the dumping line must be wound up at a faster rate than the hoisting line. One way to accomplish this is to provide an enlarged central portion on the drum whose two ends carry the hoisting and dumping lines, respectively, and a slotted flange between this portion and the portion carrying the dumping line. By a suitable shifter, this line can be thrown against the flange, and, entering one of the slots, passed over to the larger diameter, where it is in due course wound up faster than the hoisting line on the smaller diameter, and raises the end of the skip as desired.

The limitation on the two sys-

600-FOOT SPAN CABLEWAY ERECTED FOR EXCAVATING FOR SPRINGFIELD WATERWORKS RESERVOIR BY THE NEW YORK CABLEWAY & ENGINEERING CO., NEW YORK



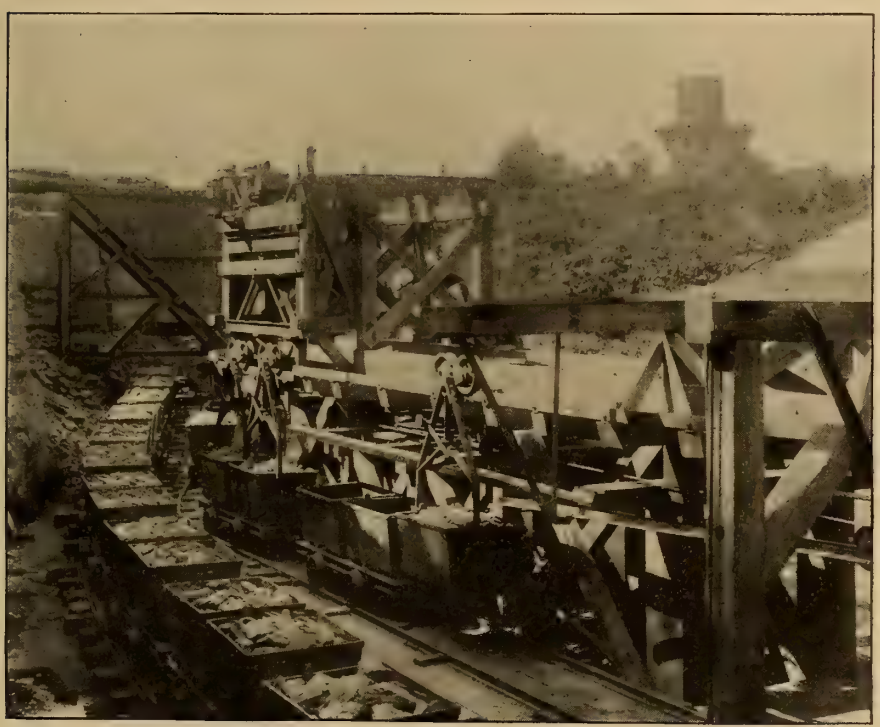
CABLEWAYS BY THE LIDGERWOOD MFG. CO., NEW YORK, AT THE CONSTRUCTION OF BARKER DAM, NEAR BOULDER, COL.

tems of dumping just described are that one will only dump while the skip is going down and the other while the skip is going up. Further, the available head room between the skip when hoisted and the top of the spoil-bank, or the side of the hopper or railway car into which the load is dumped, is diminished by the necessity of either letting down the skip in dumping it or leaving sufficient height above to allow raising one end enough to dump the contents. To reduce this lost head room as much as possible, it is usual to connect the two hoisting lines directly to the skip, instead of carrying them around fall blocks and thence to the tail tower. The speed of hoisting is then the same as the speed of the hoisting ropes, and no head room is lost by tackle blocks; but the two lines must be wound in or out with the traversing line and carriage.

The result of the combination is that dumping by clamping the dumping line and lowering the front of the skip must be done while the carriage is stationary, and does not work well for dumping into cars, for either the man in charge of the dumping cannot reach the skip to guide it, or the skip, if brought down within reach, fouls in the dumped material in the car before clearing itself. The other method, of winding in the dumping line at higher speed, can be applied only while the carriage is running towards the engine, since the dumping line can only be shifted while winding up. In order to dump near the tail tower, it would be neces-

sary to stop the carriage, and, if necessary, lower the load enough to give head room for the dumping block. If spoil-banks are to be raised at both ends of the cableway, both systems must be applied together, with all the attendant complications. These may all be avoided, and aerial dumping at any point on the line, with the carriage stationary or moving in either direction, may be easily effected by using separate and similar drums for hoisting and dumping lines. A standard three-drum hoisting engine thus actuates the complete cableway, the drums being operated together in either direction, or lowered one or more as desired, under brake control. This form of cableway engine is necessary for operating self-closing buckets of all types. As such buckets may be found necessary or convenient to deal with materials encountered in excavating, the use of the three-drum engine, in preference to the special methods of holding or winding in one line as described, insures the contractor against loss by being unable to change from the skip to bucket if unexpected conditions require it. But little extra care is necessary on the part of the engine man in keeping the skip level when using independent lines, as it is only necessary to keep the dumping line well slacked off, the skip taking its own level as it hangs by its chains from the hoisting rope.

On long spans and with heavy loads there may be trouble from the varying sag of the main cable when the carrier takes up or drops the load. The sagging of the cable in hoisting increases the amount of line to be wound in. When the load must be dropped under the centre of the span, the cable, relieved of



VIEW OF CABLEWAY LOADING TERMINAL AT THE QUARRIES. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

the load, flies up in the air. Care must, therefore, be taken to dump the load slowly, so as to avoid disarranging the carriage and lines by a violent upward jerk. With some forms of movable cableways, where the distance between towers cannot be kept uniform, the main cable is provided with some form of tension equalizer. One method is by permitting the tail tower to swing in or out, supporting it by a counterweight against the tension of the cableway. Another method employs a stationary tower with a large sheave at its top, around which the main cable is led to a counterweight below. The bending of a heavy steel cable around even the largest sheave possible to carry on a cableway tower is very objectionable, so that the counterweighting is better managed in other ways, such as the use of a bell-crank, to one end of which the main cable is fastened, or the connection of the end of the cable to a tackle which forms a short portion of the span, whose smaller and more flexible line is carried over the tower to a light counterweight. Some balancing system is required wherever cableways are supported on barges, or on floats which rise and fall with the tide, and particularly where a cableway inclines upward from a floating tower to a higher point on the shore.

An interesting modification of the cableway is the movable dumping bridge shown by the illustration. This apparatus permits of carrying filling material in railroad cars from any distant point and dumping these cars aerially under a cableway. It is possible in this way to save the entire cost of the trestle work otherwise necessary to support the construction track while the fill is being made. Instead of bringing thousands of feet of timber to remain useless under the mass of earth or rock, the contractor retains his entire outfit ready for use on the next embankment. All the advantages of cableway and construction train are thus combined. The bridge is started at one of the towers and moved forward as the work progresses, the track behind being extended as re-

TWIN CABLEWAYS WITH DERRICK, HANDLING LOGS ON THE MISSISSIPPI RIVER, AT HICKMAN, KY.
NEW YORK CABLEWAY & ENGINEERING COMPANY

quired. With the dumping bridge, the cableway is practically unlimited as to its working length, since the cars may be filled at any point, however distant, and hauled over the track to the fill.

In working with the scraper-bucket, already referred to, a very heavy drag-line is required, operated by a heavy drum geared for great power and low speed. This drum must be provided with gearing by which it can be revolved at the same speed as the traversing line in conveying the scraper to the spoil-bank. The scraper-bucket may be worked in either direction, toward head or tail tower. The bucket is dumped by a separate line and drum, revolved as required to tilt the bucket and eject the contents. The load on the drag line is regulated by adjusting the scraper so that its cutting edge takes off a layer of soil of thickness suited to the nature of the material and the available power of the engine.

The cableway is a formidable competitor of the boom derrick, a very efficient but heavy and expensive apparatus. The derrick does not possess the adaptability of the cableway to varying situations, and, besides lacking flexibility of span, is cumbersome and expensive to take down, transport and set up. The cableway, on the contrary, may be readily altered in span, taken apart, packed and shipped, and may be re-erected under different conditions for other jobs. The towers, if of wood, can be lengthened on the work if necessary, or additional steel-work can be attached. All parts can be quickly repaired or renewed, or standard ropes obtained from stock in the nearest large city to replace those worn out in service. With a multiple drum engine, all forms of bucket are available. The contractor owning a cableway equipment may fairly consider it unnecessary to charge its entire cost against the profits of one job. The probabilities are that the outfit will be equally available on following contracts and return its cost many times over.

To perceive the full measure of the future usefulness of a large cableway, and to design its parts so as to make them as serviceable as possible for future work of different character, requires cableway engineers of experience and ingenuity. With an equipment arranged and provided by a competent organization, the contractor has an outfit which will greatly increase the efficiency of his working force and enable him to bid effectively on propositions covering a wide range of work.

THE DEVELOPMENT OF THE AEROPLANE

By Henry Harrison Suplee

IN view of the present interest in the practical applications of the aeroplane type of flying machine, it is believed that some review of the principles upon which such machines are based, together with an account of some of the more successful recent devices, will be found acceptable.

Without going fully into the historical side of the subject, it is desirable to consider briefly, at first, some of the practical facts which have had a direct bearing upon the degree of success which has been thus far obtained. Leaving aside the legendary and doubtful accounts of various flying men, it may be assumed that modern aeronautics had its beginning with the first ascent of the Montgolfier hot-air balloon and the success of the hydrogen balloon of Charles, in 1783. The result of these successes, however, had much to do with the lack of effort in the development of real flying machines, since it became almost conceded that the art of navigating the air depended upon the production of an apparatus lighter than the volume of air which it displaced, and which, therefore, ascended because of the buoyancy thus produced.

As a matter of fact, the resistance of the air was well understood to be a very real thing, and its utilization for the production had long been an accomplished fact in connection with navigation upon the surface of the water. The skill with which the force of the wind has been controlled for this purpose was demonstrated by the remarkable records made by the clipper ships of the early and middle part of the nineteenth century in voyages extending halfway around the globe, at speeds comparing favourably with the performances of all but the speediest of modern steamships.

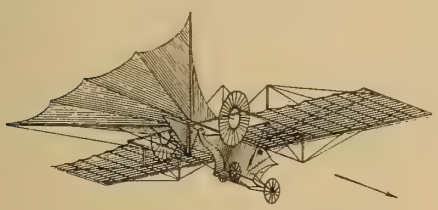
In like manner the positive nature of the action of the air in connection with the support and motion of heavy and solid bodies has been shown in the results which have been obtained in the utilization of the force of the wind acting upon the surface-planes of modern kites. The records of Blue-Hill meteorological observatory alone are convincing evidence of the power of the wind, judiciously directed, to sustain considerable weights at points several thousand feet above the surface of the earth.

It is not surprising, therefore, that, in spite of the general acceptance of the idea that a flying machine must be lighter than the air, some experimenters should have endeavored to utilize the kite principle to achieve controlled aerial navigation.

The real principles governing the action of the aeroplane appear to have been fully grasped by Sir

George Cayley, whose articles in *Nicholson's Journal* from 1808 to 1810 show a comprehensive knowledge of the subject, and an appreciation of the fact that the essential feature remaining to be secured was a light and powerful motor.

The earliest effort to construct a machine which, according to modern ideas, is entitled to be called an aeroplane, was undoubtedly that of William Henson, in 1842. Henson, who was a practicing engineer, with offices in New City Chambers, Bishopsgate, London, devised a machine which re-



HENSON'S AEROPLANE, 1842

sembled very closely the type which has since been termed the monoplane—that is, having its supporting planes practically forming a single deck, as distinguished from the box form of the biplane and multiplane devices of later inventors. As the illustration shows, there was an extended supporting surface, beneath which was attached a car, carrying an engine driving a pair of propellers. A tail, carrying additional horizontal surfaces, served for vertical steering, and beneath this a rudder was attached for lateral control. Henson planned a machine which was to have 4,500 square feet of surface in the plane and 1,500 square feet in the tail, and was to carry a steam engine of 30 horse-power. According to illustrations of the time, as well as from his British patent drawings, it appears as if this machine was very similar in appearance to the Antoinette monoplane used by Latham, and to the Bleriot machine, so successfully used in crossing the Channel. This large machine was never built, however; but, in 1844, Henson, in connection with his associate, Stringfellow, constructed models with which they made trials in 1844 and 1845, supporting the apparatus on a wire while trying out its movements. The principal difficulty appeared to have been with its lack of stability, together with the maintenance of satisfactory power, although flights as long as 40 feet were made with a little machine with planes 10 feet wide, having an area of 17 square feet, and weighing, engine and all, between six and seven pounds.

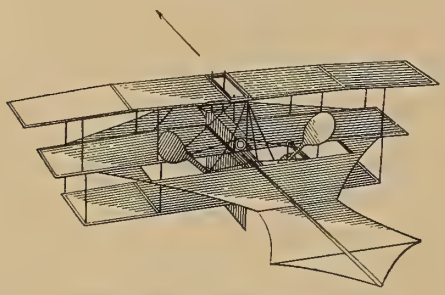
A number of experimenters followed the lead thus set by Henson; but no definite improvement appeared until, in 1866, Mr. F. H. Wenham took out a patent in England for what is now called a biplane. This idea was fully set forth by him in a paper presented before the Aeronautical Society of Great Britain, and a number of experiments made with models showed the correctness of the principle of multiplying the sustaining area by placing two or more planes above one another.

The same experiments, however, also revealed the fatal lack of stability of the machine as then made, and also showed what has since been encountered by practical aeroplanists—the prevalence of eddies and disturbing currents in the wind.

Guided, doubtless, by the theories and experiments of Wenham, there followed some important experiments made by Stringfellow, who, as already noted, had been associated with Henson. The Aeronautical Society of Great Britain announced an exhibition in 1868, and offered various prizes, which, it was hoped, would create competition, and result in the production of some practical results with flying machines. Stringfellow followed closely the original design of Henson, but added to it the idea of Wenham by placing three planes, one above the other. He also succeeded in producing a very light steam engine, and exhibited a model of the entire apparatus, experiments being made by running it along a

wire, from which it occasionally lifted itself. This apparatus received a prize from the Aeronautical Society, and Stringfellow attempted to proceed with the further development of the apparatus; but failing health and eyesight prevented, and he did little more.

Space does not permit an enumeration of all the model experiments made by the successors of these



STRINGFELLOW'S TRIPLANE, 1868

pioneers, since the fundamental principles had already thus been demonstrated. The real development of the successful machine had been shown to depend upon designs which had been perceived, but to which two essentials remained to be provided: the maintenance of equilibrium and the provision of a motor of sufficient power with light enough weight.

The question of equilibrium is still an important one, but the manner in which it might be attained for experimental purposes was pointed out very clearly a long time before it was put into practice.

Thus, in his little book upon mechanical subjects, published in 1648, Bishop Wilkins, after discussing various possible methods of solving the problem of artificial flight and suggesting the practicability of gliding flight by the aid of artificial supporting wings, proceeds:

"He that would effect anything of this kind must be brought up to the constant practice of it from his youth, trying first only to use his wings in running along the ground, as an ostrich or tame goose will do, touching the earth with his toes, and so by degrees learn to rise higher, till he shall attain unto skill and confidence.

"It is not more incredible that frequent practice and custom should enable a man for this than for many other things. What strange agility and activeness do our common tumblers and dancers on the rope attain to by continual exercise! These things may seem impossible to others, and it would be very dangerous for any one to attempt them who hath not first gradually attained to these arts by long practice and trial; and why may not such practice enable him as well for this other experiment as for these things?"

This sounds almost like a report of the methods followed by Lilienthal and afterwards by the Wright brothers in their experiments upon the attainment of equilibrium in gliding flight before attempting the use of a motor.

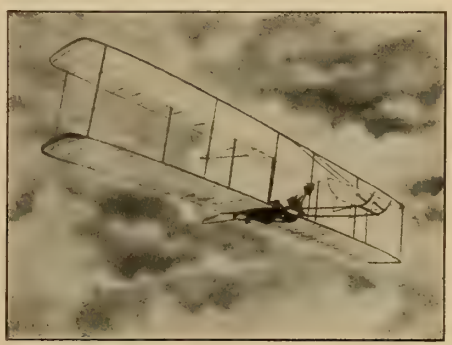
The production of a motor of low enough weight for its power to render mechanical flight practicable is the result of the efforts to develop the modern automobile, and dates from the work of Gottlieb Daimler in the improvement of the internal-combustion engine. Daimler, who had been engaged in the Otto gas-engine works at Deutz, undertook to increase the power of the gasoline motor in proportion to its weight by increasing its rotative speed, and the result of the work thus started by him and continued by others has resulted in the modern automobile engine, dispensing with the necessity of using a steam boiler, or of carrying water for making steam, and enabling engines weighing less than a kilogramme per horse-power to be provided. As a matter of fact, weights of six to ten pounds per horse-power have been found light enough for practical purposes, and it is thus possible to insure reliability and strength and yet keep within practical limits of weight.

It was in 1889 that Otto Lilienthal

published his book upon bird flight as the basis of the flying art, this including the results of years of observation and study of the flight of birds, and by 1891 he felt prepared to undertake his personal training in gliding flight.

His methods read almost precisely like those enunciated by Bishop Wilkins more than two hundred years before. Having made a pair of wings, curved to imitate the results of his studies of the wings of soaring birds, and provided his apparatus also with a rudder-like tail, he began by running along up an inclined springboard and leaping from the end into the air, and thus launching himself out on his wings. He continued in this preliminary practice until he felt sufficiently familiar with his apparatus to attempt further gliding, and so attempted outdoor flight, running down hill against a light wind, and succeeding, at his first trials in this way, in gliding distances of 60 to 80 feet. Further experiments, made from a small tower built on a hill near Steglitz, gave him a jumping-off place about 10 metres high, from which he made gliding flights several hundred yards in length, and occasionally reaching heights of 75 feet above the surface of the ground. Experience teaching him the art of balancing, he continued to glide in the face of increasing winds, until he was able to rise higher than his starting point, and occasionally to remain aloft almost stationary, supported like a kite upon the advancing air current. He was so far convinced of his success in achieving the control of his equilibrium that he was considering the application of a motor to his apparatus when, on August 11, 1896, he was overturned by a sudden gust of wind, and, falling to the ground, received injuries from which he died.

About the time of the death of Lilienthal a young Englishman, Mr. Percy Pilcher, began experiments with a gliding machine, and succeeded, both with monoplanes and biplanes, in acquiring considerable success in the art of balancing; but before he had completed his plans for equipping his glider with motive power he too lost his life by reason of the breakage of a part of the apparatus. Pilcher's death occurred in October, 1899, and it was in the following year that Orville and Wilbur Wright, of Dayton, Ohio, took up the work where it had been left off, and after experimenting with various forms of gliders and acquiring individual skill in the control of their apparatus, they successfully applied a motor, and in the latter part of 1905



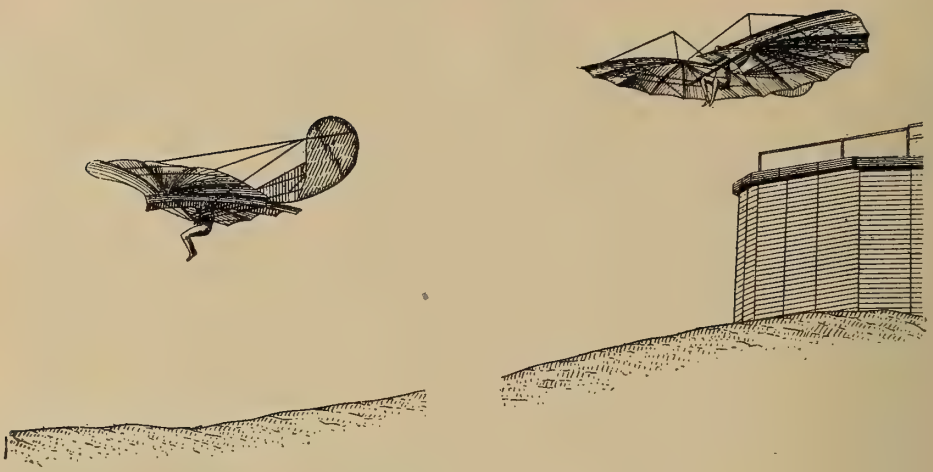
THE WRIGHT GLIDER

announced their successful solution of the problem.

The experimental work of Professor Langley, at Washington; of Mr. Octave Chanute, in Chicago, and of Sir Hiram Maxim, at Baldwyns Park, England, all contributed to the solution of the question, and to-day that question no longer stands: "Shall we ever fly?" but rather: "How shall we fly?"

We see, in this brief review of the historical side of aeroplane development, that, as in so many other instances, the successful solution of the problem had to wait until the "state of the art" reached a point where the various ideas of a number of men became capable of constructive realization.

Following the successful flights of the comparatively limited number of pioneers in the new field of engineering work there must necessarily come



LILIENTHAL AND HIS GLIDER

the development of the technical side of aeroplane construction, and just as the steamship, the locomotive and the automobile have passed from the empirical stage into the period of systematized, scientific standardization, so it is to be expected that a rational study of aeroplane construction is to become a portion of the work of the engineer.

In every new department of work great caution must be exercised in drawing conclusions from the limited amount of data available, and hence it is difficult to apply mathematical analysis, however desirable it may be to systematize the knowledge which has already been obtained. There are, however, a few mathematical principles which have a definite value in the design of apparatus for mechanical flight, and just as the scientific study of the steam engine did much to improve the machine after its practicability had been demonstrated, so we believe that an examination of the subject of the aeroplane will assist in the arrival at a better final result than the sole use of empirical methods.

When a plane surface is moved through the air at right angles to the air current it receives a pressure which is directly proportional to its surface and to the square of the velocity. If we let the area of the surface be S, and the velocity be V, we then have:

$$P = k\ S\ V^2; \qquad (1)$$

that is, the pressure is equal to the area of the surface, multiplied by the square of the velocity, and by a coefficient k, this latter being called the coefficient of the resistance of the air.

This law, commonly called the law of the square of the velocity, is approximately correct, as has been proved by the experiments of Le Dantec and of Canovetti, and more recently by the investigations of Eiffel, made upon the tower in Paris which bears his name.

Assuming the correctness of this law, it has been supposed that it might be directly applied to the problem of the aeroplane by taking any chosen angle for the inclination of a plane to the direction of its motion and then decomposing the velocity V into two others, one parallel to the inclination of the plane and the other at right angles to its surface. If we do this, and indicate by P^1 the component normal to the plane, we have:

$$P^1 = k\ S\ V^2\ \sin^2 i, \qquad (2)$$

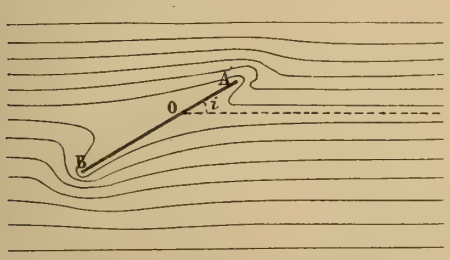
in which i is the angle of inclination of the plane to the horizontal.

This formula, which has become

famous under the name of the "law of the sine square," has been made the subject of a number of mathematical investigations; but in many instances it has been most misleading.

Soreau has shown* that the error involved in the general application of this law is due to the fact that it fails to take into account the phenomena of the flow of air, a subject which should always be kept in mind.

Thus, in the case of a moving inclined plane, the upper forward edge *A* acts upon the air somewhat in the manner of a planing tool, while the



STREAM FLOW ABOUT AN INCLINED PLANE

greater part of the surface *O—B* forces the air downward, producing eddying whirls. The pressures and suctions thus created are by no means equivalent to those which would be caused by a current normal to the plane and having a velocity $V \sin i$. As a matter of fact, the phenomena produced are of a very complex nature, and not to be reduced positively to a mathematical expression, but must be indicated according to the results of experimental investigations. We are not warranted in decomposing velocities of currents under such circumstances as if they were forces, but should first determine the forces themselves by experimental means before applying a mathematical analysis.

What we desire to compute is the amount of power which will be required to enable an aeroplane to support a given load. It will be seen at once that this depends upon several variable quantities—that is, upon the area of the surface, the angle of inclination and the speed with which the apparatus moves through the air, this latter corresponding to the velocity of the air current in the case of a kite or similar device. If we select a certain area of plane, and choose an angle of inclination indicated by experience, we may, therefore, deduce a formula which will enable the amount of power to be computed, taking into account further only the speed and the weight to be sustained.

This has been done by taking a formula originally proposed by Duchemin and tested experimentally by Langley. Duchemin's formula is as follows:

$$P^1 = P \frac{2 \sin i}{1 + \sin^2 i}, \qquad (3)$$

in which i is the angle of inclination, P^1 the pressure on the inclined surface, and P the pressure on the right-angled surface.

Substituting in this the value of P in equation (1), we have:

$$P = \frac{k\, S\, V^2 \sin i}{1 + \sin^2 i} \qquad (4)$$

In the case of all aeroplanes the angle of inclination i is very small, and hence the value of the expression will not be materially affected by neglecting $\sin^2 i$, in which case the formula (4) becomes:

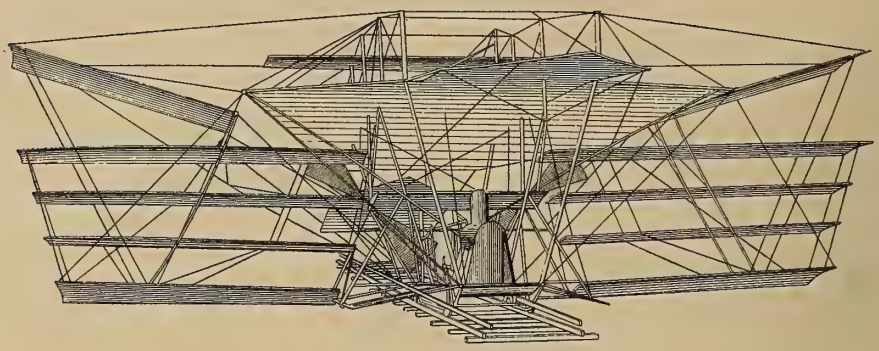
$$P = 2\, k\, S\, V^2 \sin i. \qquad (5)$$

That is, the supporting pressure is directly proportional to the area of the plane, to the square of the velocity, and to the sine of the angle of inclination. The constant $2\,k$ includes the influence of the form of the plane upon the resistance, and must be determined by experiment.

The most available experiments for the determination of this value are those of Professor Langley. These give for a plane surface a value $k = 0.004$, taking the pressure in pounds per square foot and the velocity in miles per hour.

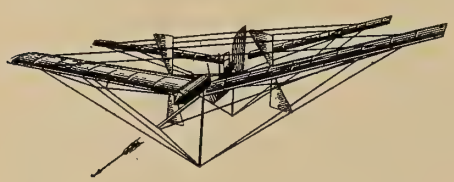
An examination of formula (5)

* Mem. Soc. Ing. Civ. de France, July, 1908.



THE MAXIM AEROPLANE

shows that the sustaining force P increases very rapidly with the velocity, the proportion V^2 indicating that if the speed is doubled the supporting pressure is increased four times, while if the speed is trebled the support becomes nine times greater. Consequently, for the same supporting power the area of the surface S may be correspondingly reduced, or for the same surface a correspondingly greater load may be carried.



PROFESSOR LANGLEY'S AEROPLANE

The surfaces of aeroplanes are generally given a slight amount of curvature, and this has a sensible influence in preventing eddy losses, etc. This is shown by applying the formula (5) to an actual machine with curved planes, and, after inserting the actual values, solving the equation for k. Thus, Major Squier shows that in the Wright aeroplane, taking the following actual values:

$P = 1{,}000$ pounds,
$S = 500$ square feet,
$V = 40$ miles per hour,
$i = 7$ degrees,

and substituting them in equation, transposed for k we have:

$$k = \frac{P}{2\,S\,V^2 \sin i \over 1{,}000} \qquad (6)$$

$$k = \frac{}{2 \times 500 \times 40 \times 40 \times 0.12187} =$$

0.005035.

This is more than 25 per cent. greater than Langley's experiments showed for plane surfaces.

In order to compute the power required for propulsion, we must consider the resistance which is opposed to the movement of the whole apparatus. This resistance consists of two parts, that due to the support of the load and that due to skin friction.

The resistance due to the support of the load is equal to $P \tan i$, while the skin resistance has been ascertained, after an elaborate series of experiments by Dr. Zahm, to depend upon a coefficient f, which varies as the 1.85 power of the velocity.

The general formula for the resistance is, therefore:

$$R = P \tan i + 2\,f\,S,$$

in which, as before, i is the angle of inclination; P the sustaining power, practically equal to the total weight carried; S the area of the planes, and f the coefficient of skin friction per square unit of area.

According to the researches of Dr. Zahm, the value of the coefficient f is obtained from the following:

$$f = 0.0000158\ l^{-0.07}\ v^{1.85}, \qquad (7)$$

in which f is the length of the surface and v is the speed in miles per hour, this value of f being the average skin friction per square foot of surface.

Having thus determined the resistance R and the velocity v, we may compute the power, which will be equal to the product of the resistance in pounds multiplied by the speed in feet per minute divided by 33,000, or:

$$H.P. = \frac{R \times 5280\, v}{33{,}000} \qquad (8)$$

We see from the above formulas that the supporting power of an aeroplane varies with the square of the speed; but in order to maintain a high speed the power, and hence the weight of the motor, as well as the weight of the fuel to be carried, must be considered. Still there is a gain in operating at a high speed, since it is only the weight of the propelling machinery which has to be increased in order to attain a greater velocity, and this forms but a portion of the total weight to be carried.

If we take equation (5) and make P and S constant, and consider various values of the velocity V, we may compute the power required for different angles. Investigations of this nature show that the best results are obtained with angles of 3 to 4½ degrees and velocities of 40 to 50 miles per hour. It is also shown that the greatest weight which can be supported by one horse-power under these conditions is about 90 pounds, so that if the weight of the machinery is 9 pounds per horse-power developed, about 10 per cent. of the total weight supported must be given to the machinery. This moderate weight of machinery has been already attained, and even smaller weights found practicable, so that a very fair proportion of the supporting power of an aeroplane is available for useful service.

Having thus considered the general principles governing the design of aeroplanes, we will follow with some description of actual forms of machines with which flights have been made.

(*To be concluded.*)

THE DESIGN OF SHIPS' RUDDERS

By R. J. Grimshaw

With the increasing development of speed and power in modern vessels, the question of prompt and powerful control becomes more and more important. For this reason, the study of the methods of designing and proportioning of the rudders of ships in such a manner as to insure the best balance and the most effective response demands the attention of the marine architect and engineer, and in the following article Mr. Grimshaw has placed the latest accepted formulas and methods in a form for convenient use.—THE EDITOR.

THE principal things to be determined in the design of a ship's rudder *ab initio* are:

(1) Its area and shape;

(2) The normal pressure on the rudder, ahead and astern;

(3) The position of the center of pressure of the rudder when going ahead and astern.

When these points are established the detailed dimensions of the rudder can readily be ascertained.

AREA

In determining the area regard must be paid in the manoeuvring qualities of the vessel. The naval architect has at his disposal information concerning the manœuvring qualities of somewhat similar ships, and the usual practice is to express the relation as a ratio the area of the immersed part of the rudder to that of the immersed part of the middle-line vertical plane; the conditions of lading approximating the same in the ships taken as examples. In this way we get various values for the ratio:

$$\frac{\text{area of immersed rudder}}{\text{area of immersed middle-line plane}}$$

Expressing this ratio as $\frac{l}{K}$ it will be found that the value of K does not vary greatly, ranging usually from 38 to 45.

Having ascertained the value of K in a somewhat similar completed ship, it is easy to deduce a suitable value for the ship under consideration, allowance being made for any desired difference in manœuvring qualities. Thus, an increase of rudder area is influential in diminishing the path traversed in turning. Attention must also be paid to the probable list of the ship in turning, since an abnormally large rudder, while reducing the diameter of the path in which the vessel turns, may cause an excessive increase in the centrifugal force acting at the center of gravity of the ship, and consequently give an undesirable and possibly dangerous list in turning at high speeds.

FORM

The area being settled, the form has to be determined. The balanced rudder is the most advantageous form to be adopted on account of the smaller twisting moment at the rudder head, and consequently lighter steering gear and steering engine required. It is usual, in the balanced rudder, to place one-third of the rudder area before the axis of the rudder and two-thirds abaft the axis. With very high-speed vessels with very deep rudders, as in the case of torpedo craft, the ratio

$$\frac{\text{area before axis}}{\text{area abaft axis}}$$

may have the minimum ratio of 1/3.

NORMAL PRESSURE

The normal pressure on the rudder, both in going ahead and in going astern conditions, is very satisfactorily given by the formula:

$$\text{Normal pressure in tons} = \frac{K.\,A.\,V.^2 \sin\theta}{2000}$$

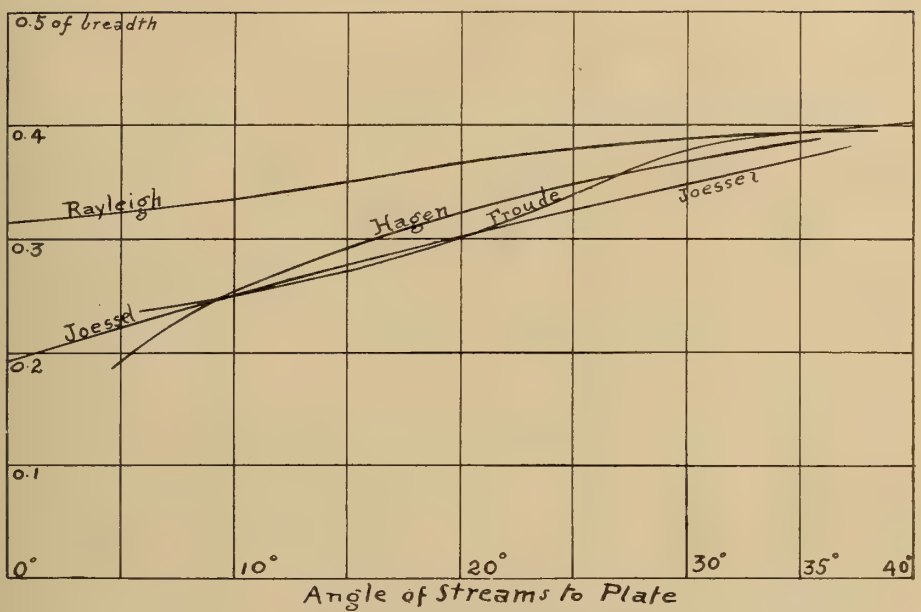


FIG. 1.—GRAPHICAL REPRESENTATION OF FORMULAS FOR DISTANCE OF CENTRE OF PRESSURE FROM LEADING EDGE, FOR RECTANGULAR PLATE

in which

A = area of immersed rudder in square feet.

V = velocity of the streams past the rudder in feet per second.

θ = the angle which the plane of the rudder makes with the direction of motion of the streams.

A usual value of K is unity, so that the formula for the normal pressure is thus reduced to:

$$\text{Normal pressure} = \frac{A.V.^2 \sin\theta}{2000}$$

The above formula is entirely empirical and is based on experimental results, experiments having been carried on by Beaufoy, Joessel and Froude. The formula is not by any means perfect, and doubt exists as to its accuracy for quantitative results. Practice, however, has demonstrated that rudder dimensions based on its application are quite satisfactory.

POSITION OF CENTER OF PRESSURE

The position of the center of pressure of a rudder can be determined from the experiments of Joessel, Froude and Hagen, and the mathematical investigations of Lord Rayleigh. These experiments were made with rectangular plates. The results are expressed in the formulas given below, in which b is the breadth of the rectangular plate; d the distance of the center of pressure from the leading edge of the plate, and α the angle of the plate to the direction of motion.

$d = 0.195\ b + 0.305\ b \sin\alpha$ (Joessel)

$d^2 = (b - d)^2 . \frac{\alpha}{90^\circ}$ (Hagen)

$d = \frac{b}{2} - \frac{3}{4} . b \frac{\cos\alpha}{4 + \pi \sin\alpha}$ (Rayleigh)

These results are shown graphically in the curves of the accompanying diagram. Fig. 1.

It is usual to employ the results of Joessel in determining the center of pressure of a rudder, and in such case it will be found that for a rectangular rudder at an angle of 35 degrees, the distance of the center of pressure from the leading edge may be taken as sensibly equal to *three-eighths* of the breadth of the rudder.

TABLE SHOWING METHOD OF DETERMINATION OF AREA AND CENTRE OF PRESSURE AHEAD AND ASTERN FOR AN OVAL RUDDER AT AN ANGLE OF 35 DEGREES TO DIRECTION OF STREAMS.

No. of Ordinate.	Ordinate.	Simpson's Multipliers.	Functions for Area.	Ahead: Centre of Pressure from Axis.	Ahead: Functions of Moment.	Astern: C. P. from Axis.	Astern: Functions of Moment.
1	y_1	1	y_1	p_1	$p_1 y_1$	q_1	$q_1 y_1$
2	y_2	4	$4y_2$	p_2	$4p_2 y_2$	q_2	$4q_2 y_2$
3	y_3	2	$2y_3$	p_3	$2p_3 y_3$	q_3	$2q_3 y_3$
4	y_4	4	$4y_4$	p_4	$4p_4 y_4$	q_4	$4q_4 y_4$
5	y_5	2	$2y_5$	p_5	$2p_5 y_5$	q_5	$2q_5 y_5$
6	y_6	4	$4y_6$	p_6	$4p_6 y_6$	q_6	$4q_6 y_6$
7	y_7	2	$2y_7$	p_7	$2p_7 y_7$	q_7	$2q_7 y_7$
8	y_8	4	$4y_8$	p_8	$4p_8 y_8$	q_8	$4q_8 y_8$
9	y_9	1	y_9	p_9	$p_9 y_9$	q_9	q_9
				M_1		M_2	M_3

The area of rudder will then be equal to $M_1 \times \frac{1}{3}$ common interval between ordinates.
The centre of pressure going ahead $= M_2 \div M_1$.
The centre of pressure going astern $= M_3 \div M_1$.

For a rudder of oval form the center of pressure may be determined by an application of Simpson's rules, as in the table and as shown in Fig. 2.

The procedure is to divide the rudder area into parts, by equidistant ordinates drawn horizontally. The center of pressure of any horizontal strip of the rudder, of small depth, approximates to that of a rectangular plate of the same dimensions; the center of pressure of such a rectangular plate, both ahead and astern, may be found from Joessel's formula; so that it is necessary only to set back from the end of each ordinate a point three-eighths of its breadth. The points so obtained represent the centers of pressure of the small strips of rudder of which the ordinates are the middle lines. These points determine curves of the centers of pressure, both ahead and astern, and by applying Simpson's rule to these curves, we obtain the centers of pressure, both ahead and astern, for the whole rudder. It is evident that the greater the number of ordinates taken, the more accurate will be the result.

We have now indicated the manner in which the area, shape, normal pressure and position of center of pressure can be determined.

By treating the rudder as a loaded beam, subject to both twisting and bending stresses, and taking into account the method of support at the stock and at the pintles (if any), the principal dimensions of the rudder may be determined. Thus, in the case of a rudder supported at two pintles, as in the illustration, Fig. 3, we have: The bending moment at the head (M) = normal pressure ($N.\ P.$) $\times$ 0.208. If T denotes the twisting moment at the head, the diameter of the head is given by:

$$\frac{\pi}{16} f \cdot d^3 = M + \sqrt{M^2 + T^2}$$

in which f = working stress permissible. The force on the middle pintle is equal to 0.56 times normal pressure. Assuming this to be uniformly distributed over the pintle we have for the bending moment at the root of the pintle = 0.56 $N.\ P.$ $\times$ ½ depth of pintle; from which the diameter of the pintle is readily determined. The dimensions of the lower pintle can be found in a similar manner, the force on the pintle being 0.187 of the normal pressure.

Another example, that of a balanced rudder, supported entirely at the head, may be taken. Fig. 4.

The area of this rudder was 195 square feet. The speed of the ship (turbine driven) was 20 knots. The maximum rudder-angle was 35 degrees. By the method already indicated, the center of pressure ahead was 6 inches for the axis and the center of pressure astern was 48 inches; both being half-way down the rudder.

Normal Pressure.—Going ahead the speed of this ship was 20 knots; the vessel being turbine-driven, a slip of 25 per cent. may be expected. This will increase the speed of the streams past

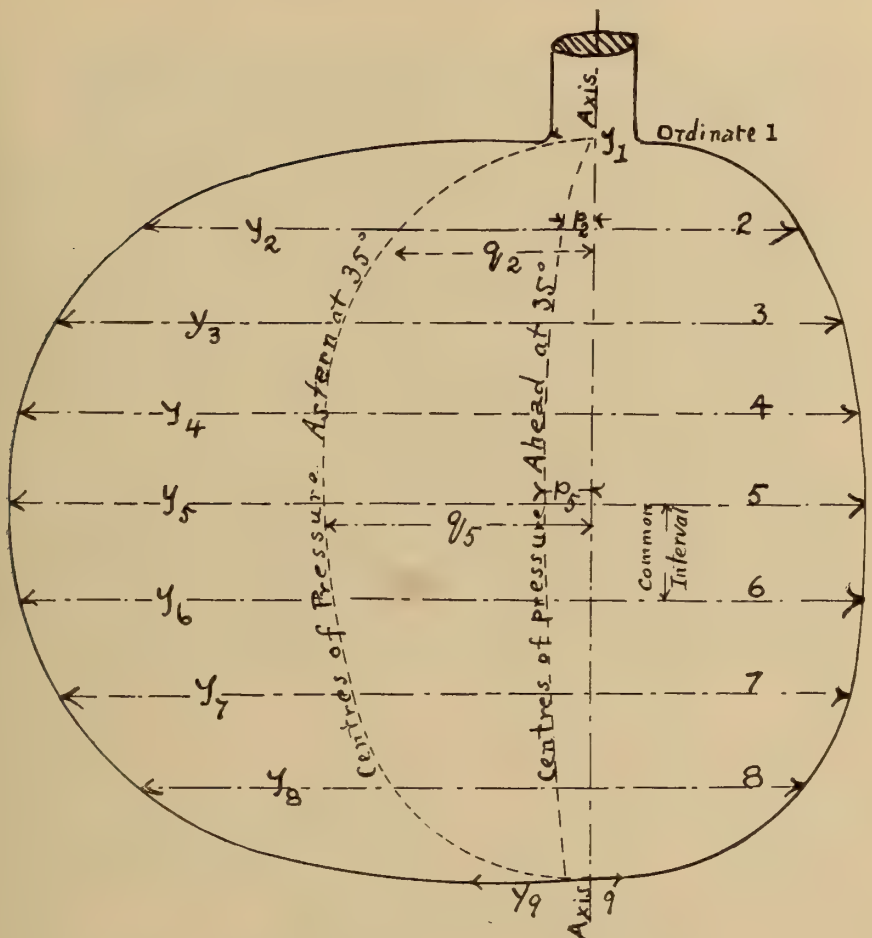


FIG. 2.—DETERMINATION OF CENTRE OF PRESSURE OF A RUDDER

the rudder to 25 knots, and the normal pressure works out to nearly 100 tons. Going astern, the speed of the streams may be taken as that of the ship, unless they are immediately contiguous to the rudder. Assuming this not to be the case, and taking the power of the astern turbines as sufficient to drive the ship astern at two-thirds of the speed ahead, we have the normal pressure astern reaching 53 1/3 tons.

Size of Stock and Rudder Head.—In this type of rudder, supported entirely at the head, the stock must resist the whole of the bending and twisting due to the normal pressure, and the head must be large enough to resist stresses due to the twisting.

Considering the section at A-A, when going ahead, the equivalent twisting moment works out to 16,224 ton-inches, and when going astern it becomes 9,320 ton-inches. Thus it will be seen that the ahead condition produces the greater stresses in the stock.

If d denotes the diameter of the stock at A-A, we have: Equivalent twisting moment $= \frac{\pi}{16} f \cdot d = 16{,}224$ ton-inches, and taking f as equal to 5 tons per square inch, we get: $d =$ diameter of stock $= 25\frac{1}{2}$ inches.

As regards the rudder head, which

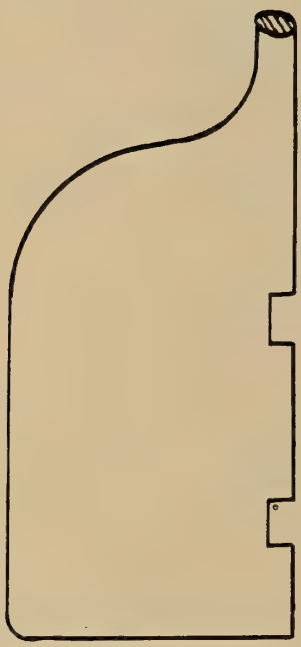


FIG. 3.—RUDDER WITH TWO PINTLES

is designed to take only the twisting moment, we have:

Twisting moment (ahead) = 100 × 6 ton-inches.

Twisting moment (astern) = 53 1/3 × 48 ton-inches = 2,560 ton-inches. Hence, if d be the diameter of the head, using the formula

$$T = \frac{\pi}{16} f \cdot d^3$$

and taking f at 5 tons, we get: d = 13¾ inches.

The length of the stock is governed by the bearing pressure allowable between the gun-metal bush and the steel of the rudder. Allowing 250 pounds per square inch, if l be the length of the stock, we have:

$$250 \times l \times 25\tfrac{1}{2} = 100 \times 2{,}240 \text{ lbs.}$$

$$l = 36 \text{ inches,}$$

and hence the minimum length of the stock is 3 feet.

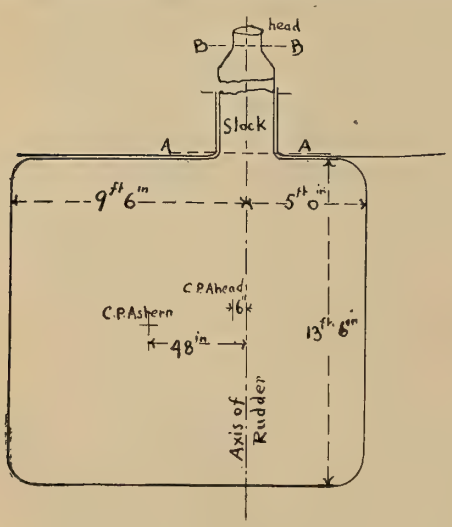


FIG. 4.—CENTRES OF PRESSURE OF BALANCED RUDDER

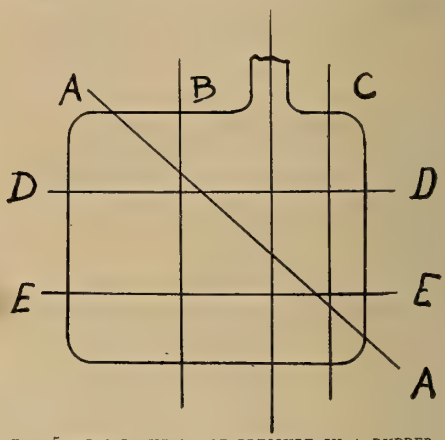


FIG. 5.—DISTRIBUTION OF PRESSURE IN A RUDDER

The sizes of the other parts of the rudder frame can be determined by taking sections as at *A-A*, *B-B*, etc., Fig. 5, and assuming that the material of the frame must be sufficient to resist the whole of the bending due to water pressure; the rudder-plating itself being considered as contributing nothing to the strength. The center of pressure of each area so cut off by such a section as *A-A* can be taken at the centroid of the area cut off; that is, we are assuming a uniform distribution of pressure over that area. We are well on the safe side in making this assumption, since the intensity of pressure over the rudder decreases as we recede from the leading edge. The rudder plating undoubtedly helps to resist the bending, but it is usual to neglect this unless the strength of the

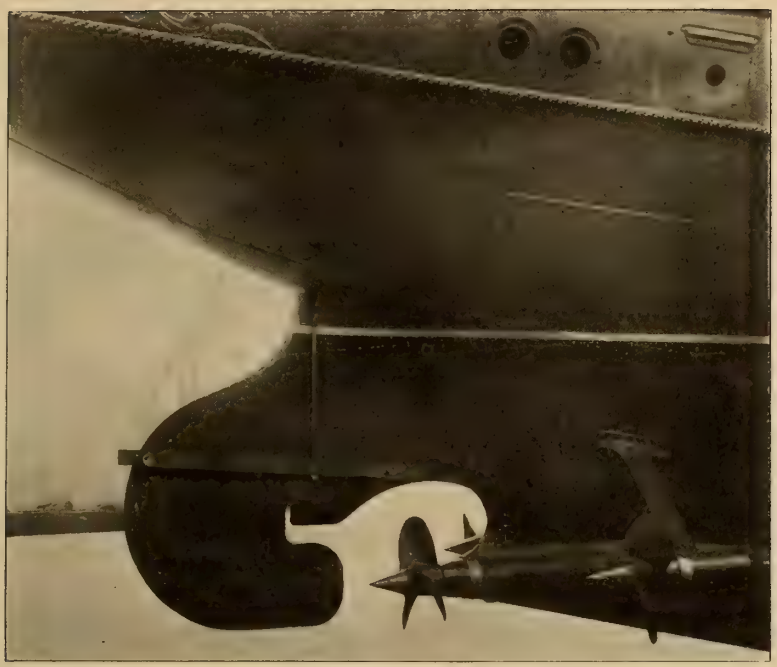


FIG. 6.—A MODERN BALANCED RUDDER
The rudder is shown clamped in position during the launching of the vessel

plating is maintained at the laps or butts, by suitable connections, as is sometimes done in torpedo craft.

It will be seen that, owing to the fullness of the horizontal section of a rudder, the effective angle of the streams is increased on one side and decreased on the other, the net effect being to increase the angle of the streams and so increase the normal pressure. On the other hand, it takes an appreciable time to put the rudder over, and when the latter attains its full angle the vessel has lost way, and the speed of the streams, and consequently the magnitude of the normal pressure, is very considerably reduced. The angular velocity which the ship takes up when the rudder is put over has also the effect of diminishing the effective angle of the rudder to the streams.

In slow-speed sea-going vessels it is obvious that a rudder calculation based on the speed of the streams past the rudder would give very small rudder dimensions. It is usual in such cases to determine these dimensions from a consideration of the action of the waves rather than from the effect due to the streams. A very good approximation to the effect due to wave action is given by obtaining the normal pressure upon the assumption that the streams are moving past the rudder at about 15 knots.

Current Topics

IT has been said that "foresight" is better than "hindsight," but to this rather trite statement may be added what is sometimes overlooked, that we may often safeguard the future by the lessons of the past.

During the past few years the outcry about the reckless waste, and still more reckless exploitation, of natural resources has become so insistent that it would seem as if little or nothing remained of the valuable stores of raw material with which the civilized parts of the world were originally endowed. We have endeavored, in recent issues of this magazine, to call attention to the vast stores of valuable materials yet awaiting development in many accessible parts of the world, and the articles upon the wealth of mineral and vegetable resources in Siberia, Alaska and Japan have already been discussed in these pages by competent specialists, while similar articles upon other and even richer parts of the world are yet to appear.

Having these stores of natural wealth still before us, it would seem even more criminal to proceed in the same wasteful method of handling with these supplies which provokes so much reproach in connection with the exploitations of the past. Yet this is what seems about to be done unless public opinion is roused and the looting of Nature's storehouses is placed under rigid control.

In the article upon the natural resources of Alaska, published in the October issue of this magazine, it was shown there are nearly fourteen thousand square miles of coal-bearing lands, and it has been estimated that there is available in this area at least 15,000 million tons of high-grade coal. A large part of this area is yet under the control of the United States Government, but, unless immediate and positive action is taken, it will pass from public ownership into the hands of irresponsible private parties, by whom it will surely be wasted as recklessly as have the deposits of the older States.

It remains for the present session of Congress to take such action as will save for the future this heritage of the nation, unless it has already been decided that conservation of natural resources is a matter for talk only and not for action, and that the whole agitation is intended to throw dust in the eyes of the public, while the real and positive action is being taken in behalf of the private interests, which are ready and active with plans for the introduction of the same wasteful methods which have been so unsparingly condemned in public and practiced in private.

WE referred some time ago to the process of deepening harbours, which is in progress all the world over. The decay of so many old ports has arisen less from economic factors than from physical. Modern ports such as Liverpool have been able to survive because their destruction by natural forces, such as silting up, bar formations and other causes, have been countered by the aid of mechanical forces. Without powerful dredgers, Liverpool must have been very seriously hampered. Only a few years ago, so careless did the Liverpool port authorities become of their port's interest that the low-water depth on Liverpool bar was allowed to become as little as 11 feet. Indeed, we believe it was even but 7 feet at one time. But Southampton, with its natural deep water, backed by the strenuous efforts of a powerful railway company, caused so much loss to Liverpool, and so much prospective loss, that dredging was set about in earnest and now the Mersey bar is practically non-existent for the largest vessels at all states of the tides.

The Canadian Marine Department, stirred to action by the growth of steamships, has now decided to dredge the channel of the St. Lawrence River, so as to give a minimum depth of 35 feet all the way to the sea. The work will be commenced next year, with the aid of several new dredgers now about to be built at the government yard at Sorel, where there is already under construction a dredge which, when built, will be the largest in the world. All this is being done for the port of Montreal, which can only be used for half the year, for it is sealed up for five to seven months in winter. How much more important, then, must deep water be for the ice-free port of the world generally!

THE advance of marine engineering in the few short years of the present century is related in a paper by Mr. Maginnis at the Liverpool meeting of the Institution of Mechanical Engineers.

Since 1872, pressures have advanced each decade as follows, approximately: 52, 77, 158, 197, 195 pounds per square inch. Coal consumed per indicated horsepower hour has been 2.11, 1.83, 1.52, 1.48, 1.48. Thus the turbine has apparently checked further rise in pressure, and has not reduced coal consumption. Any possible further coal economy has been, in fact, sacrificed to other advantages, though we may hope to see the reduction of coal per horsepower hour continue after a period of rest.

No turbine steamer has been towed into port, and no sailing schedule has been upset by failure thus far.

The chief trouble with turbines has been the ratio of the turbine speed to the propeller speed. It is anticipated that there should soon spring up a revival in the re-engining of vessels similar to the revival in the Seventies, when simple engines were changed to compounds.

There are now sixty-four turbine steamers in the merchant service of 603,200 horsepower; this is up to December, 1908. In 1901 there was but one such steamer, of 3,500 horsepower. A good deal is being done in combining high-pressure engines with low-pressure turbines, or, rather, in adding a turbine to triple or quadruple engines, which exhaust at so high a pressure that a turbine will work very well on the remainder with a good vacuum.

The propeller question is still very empirical. The improved results with the great Cunarders, which at first were, in a sense, failures in regard to required speed, have been got by varying the propellers. This reminds one of the steamships *Iris* and *Mercury* in 1878, when huge improvements were made by changing the propellers. It all shows that very little is really known about propellers.

Boilers have not changed much except that they are built of larger plates with fewer rivets. The largest plate rolled measures 42 feet by 9 feet 6 inches by 1½-inch thick. It weighs

nearly 11 tons, and is in the boiler of a Liverpool tugboat, the *Knight Errant.*

The lower pressure possible with turbines has meant a saving of 120 tons in boilers alone in the great Cunarders, as compared with what would have been required for reciprocating work.

Marine work is backward in the moving and firing of coal. Liquid fuel, of course, gets over all such difficulties, and suggests that if coal could be bunkered in the form of fine dust and burned in that form it might be possible to arrange some mechanical means of conveying it to the furnaces.

Liquid fuel is practically equal to double its weight of coal, yet occupies less space. There are no dirty fires with liquid fuel; a ship is better kept to speed. Fewer hands are needed, fuel can be carried in the double bottom, and the ship trimmed by sea water as the fuel is burned, and fuel can always be used so as to avoid a list. Bunkering is merely a matter of pumping. Travelers would esteem the change from the present coaling at Port Said. East of Suez, liquid fuel is cheaper than coal.

With liquid fuel applied to the *Lusitania,* there would be 27 firemen instead of 312, room for 200 more passengers and 5,000 tons of cargo, so that it should be worth £7,000 per voyage. Unfortunately liquid fuel is scarce. Its production is comparatively small, and if largely adopted the enhanced price would much reduce the economy at present apparent.

Internal combustion engines have so far made little progress on shipboard.

There is some talk of electric driving and of using turbines and high-speed generators and slower electric motors. The propeller could then be controlled from the bridge.

The electric turbine drive seems to be best adapted for the tramp steamer, with its moderate propeller speed.

Modern ships have a tendency to revert to more moderate speed, and it appears to be thought that the *Mauretania* and *Lusitania* will not be equaled for a long time.

ONE of the first results of the discovery of oil in Mexico has of course been the diminution of coal imports. Formerly the Mexican railways consumed annually at least 120,000 tons of patent fuel from South Wales. In the latter half of last year half the locomotives were altered to burn liquid fuel, and it is now only a question of providing the necessary oil-storage tanks at suitable points for oil fuel to become universal. Other industrial power plants are being converted to oil fuel and the import of solid fuel is reduced by about one-half. Mexico is well off also in electrical power generated by waterfalls. The celebrated El Oro mines are supplied by electricity transmitted from long-distant falls. Industrially, Mexico is moving rapidly at present, and it affords a great field for the useful employment of capital, and British manufacturers should take a hand in the development of the country. There is a field for oil engines and gas producers.

SPENCER MILLER

A BIOGRAPHICAL SKETCH

IN certain departments of engineering it sometimes occurs that some one name is closely associated with their development. It is in this manner that one thinks of the cableway when the name of Spencer Miller is mentioned, since for the past twenty-one years he has been actively concerned in its improvement and application, as well as in kindred departments of engineering work.

Spencer Miller was born in Waukegan, Ill., in 1859, and received his technical education at the Worcester Polytechnic Institute, Worcester, Mass., from which he was graduated in 1879. His first work after graduation was that of special tutor in mathematics at Amherst College, after which he went to Chicago and became a draughtsman for the Link-Belt Machinery Company, afterwards entering the sales department of the same company. During this period he designed a number of rope drives, as well as novel arrangements for handling merchandise by continuous systems of conveying.

It was in connection with the use of rope driving with grooved pulleys that he devised the method of equalizing the grip upon pulleys of different diameters by varying the angle of the grooves, this invention being fully described in a paper entitled "A Problem in Continuous Rope Driving" presented by him before the American Society of Civil Engineers on December 15, 1897.

Twenty-one years ago Mr. Miller became an engineer-salesman for the Lidgerwood Manufacturing Company, of New York, and at once took up the subject with which he has since become so closely identified, the wire-rope cableway.

At that time the Lidgerwood Company were building the cableway system devised by Milo W. Locke, an apparatus of which the effectiveness was much impeded by the old-fashioned fall-rope carriers of the chain-connected type with which it was equipped. Mr. Miller took this crude apparatus in hand, and, by the invention of the "button-stop" fall rope carried, gave the problem a practical solution.

Several hundred cableways of this type have been supplied for all kinds of service to all parts of the world, being used in the construction of dams, filtration beds, sewers and similar work, as well as in open mining. Thirteen Lidgerwood cableways have recently been installed on the work of the Panama Canal, and within a few months the number of cableways sold by the company will number one thousand. Mr. Miller is still engaged in making improvements in cableways, and expects soon to be able to show that a load carriage may be propelled along a suspended cableway in regular service at a speed of 3,000 feet per minute.

After establishing a cableway department and educating his assistant engineers to act independently, he next directed his energies to the solution of a most difficult problem, that of taking cypress logs out of the swamps of Louisiana. Owing to difficulties in handling the logs these

timber lands were valued at only $1 per acre, on which 50,000 feet of timber was standing. By the invention of the Lidgerwood log-skidder this question was solved, and the cost of logs at the mill was reduced from $8 per thousand to $3.85 per thousand. The result of the introduction of the Lidgerwood skidder was an increase in the capacity of the sawmills from 50,000 feet of timber per day to 250,000 feet, and a great advance in the value of the timber lands. The success of this apparatus led to the general use of improved methods of logging by steam in various parts of the country, not only in the South, but in the Northern States and in Canada, where snow was previously depended upon to aid in transport of the logs.

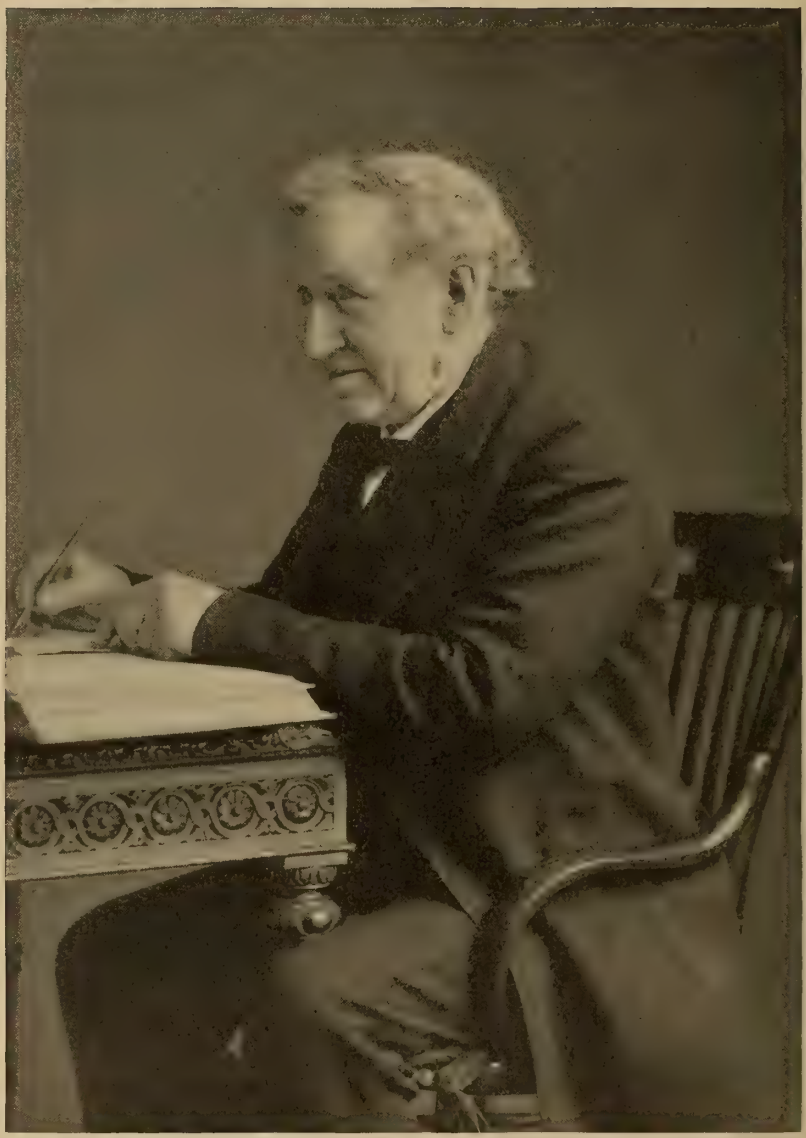
At the outbreak of the Spanish war in 1898 the question of coaling ships at sea became an important one, and the Lidgerwood Company entered into a contract with the United States Navy Department for a cableway capable of transporting coal from ship to ship under a headway at sea. Mr. Miller designed a successful marine-cableway for this purpose, and this apparatus has grown from a machine with a capacity of 15 tons per hour to 80 tons, and has been employed with success in the naval service of Great Britain, Japan, Russia, Italy and the United States.

A most interesting modification of the marine cableway has been successfully designed and operated by Mr. Miller for life saving at sea, this being a new type of breeches-buoy apparatus.

A later appliance for similar service designed by Mr. Miller involves the method of "broadside" coaling in harbour, and five American colliers have been equipped with this type of marine transfer. The apparatus consists of a pair of special winches and a novel form of rope-lead for handling a clamshell bucket, so that each collier becomes a floating coaling-station, capable of as rapid service as a shore coaling-tower. As an example, the collier *Hector,* equipped with the broadside system, discharged 190 tons of coal per hour from a single hatch, this work requiring the services of only two men, while the old method would have required 150 men, could such a number have been able to work in one hatch. The capacity under the old conditions was about 20 to 25 tons per hatch per hour, and the government requirement for the new apparatus was 100 tons, while the test gave the result of 190 tons, as above noted.

Mr. Miller is still in active engineering work, and is as indefatigable in the development of improvements as ever, being devoted to his labours, and expects to remain in harness indefinitely.

He is a member of the American Society of Civil Engineers, of the American Society of Mechanical Engineers, of the American Institute of Mining Engineers, and of the Society of Naval Architects and Marine Engineers, as well as the Canadian Institute of Mining Engineers. He is also a member of the Engineers' Club, of New York; Essex County Country Club, of Orange, N. J., and of the Metropolitan Club, of Washington, D. C.



Photograph by Elliott & Fry, London

JAMES NASMYTH

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THE NATURAL RESOURCES OF NEW ZEALAND

By W. Wilson, B. E.

ONE of the most surprising characteristics of the Dominion of New Zealand is the great variety of its products. Although its total area barely exceeds 100,000 square miles, quite a large variety of climate and country is met with in its different districts, each of which, consequently, has its distinctive resources, these in many cases being very numerous. Especially is this true with regard to the mineral kingdom; and when we consider that considerable areas have not even been trodden by human foot, we almost wonder whether anything exists that could not be found there. The small population of just under a million are developing these resources more and more, but still only a humble proportion of the total products are being exploited. In the near future, however, the improvement of railway facilities will do much to render valuable properties accessible and to facilitate the opening up of new projects.

I propose to preface a consideration of these natural resources with a brief description of the country itself. As will be seen from the map, New Zealand consists of two main islands, known as the North and the South, respectively, stretching from about latitude 34° to latitude 47° S., a total extent of 1,100 miles. The climate varies considerably over this length, especially as much of the country is more than one thousand and two thousand feet above the sea. Snow is quite unknown in the North Island, except on the high central regions, while winter, as a cold season, is practically non-existent in Auckland, the most northern city. On the other hand, Dunedin and Invercargill, large towns in the southern province of Otago, have snow almost every year, and the sheep country in the uplands of the interior is subject to heavy falls that sometimes amount to many feet in depth. The character of the country is equally diverse, fertile plains and mountain chains existing side by side in some parts. The North Island is less mountainous than the South, and possesses a larger proportion of agricultural land. Active volcanoes and hot lakes occur in this island only, and extinct volcanic remains and volcanic soils are very common. The South Island is largely divided into two unequal strips by a lofty range with peaks of over 12,000 feet in height. The eastern of these portions is, in general, flat and very fertile, while the western is heavily wooded and richly impregnated with minerals. Glaciers occur in the di-

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MAP OF THE NEW ZEALAND ISLANDS

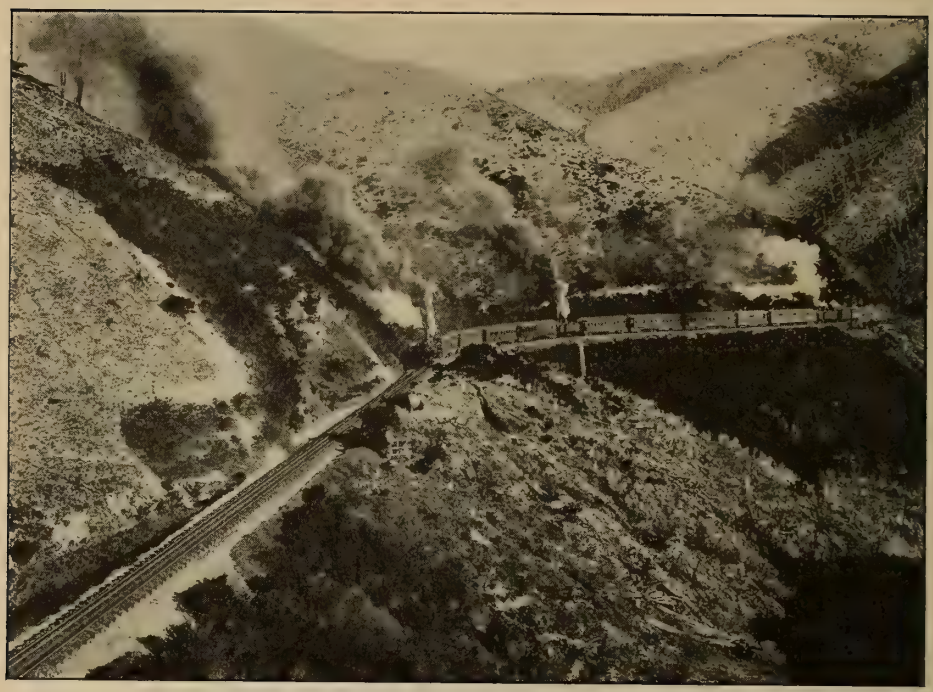
viding chain of as much as 18 miles in length. The detritus from these and larger ones of a distant past has enriched the soil of the plains to a remarkable extent. Thus it can be seen that opportunities exist in these islands for many different industries.

New Zealand is known to the vast majority of those acquainted with her as a pre-eminently meat-producing country. Her inhabitants certainly owe much of their prosperity to the pastoral and agricultural pursuits for which so much of the land is excep-

tionally suited. Configuration and position have united to bequeath on her a most favourable climate, in which droughts and blizzards find no place. The soil is good, though varied, in both islands, and the water-supply, thanks to the numerous rivers, very abundant. Consequently, we find that, out of the total exports of over £20,000,000, about £17,000,000 were derived from the soil. I shall, therefore, begin by describing the farming resources of New Zealand.

PASSENGER TRAIN IN THE OTIRA VALLEY, NEW ZEALAND

The province of Canterbury, on the eastern coast of the South Island, is, by reason of the fine quality of mutton exported therefrom, the best-known of the farming districts. It consists principally of a broad plain, bordered by the sea, of a maximum width of about forty miles, a length of about a hundred and forty, and a total acreage of over 3,000,000. It is well watered by evenly-spaced rivers flowing from the western mountains to the sea, and its flatness is scarcely broken by hill or valley. Railway construction is, therefore, an easy matter, and every advantage was taken of this fact by the colonists, who, a few years after their arrival in 1851, had started the first railway system in the Colony. The land was thus quickly opened up, and, thanks to the enterprising methods of the settlers, the products soon became famous, and have commanded a ready market ever since. Their success quickly spread to the rest of the provinces, and among the hills in the north and south the soil is yielding pasture and grain in abundance. There are, in Canterbury, over 150,000 acres in wheat alone, the production of which reaches as high as 60 bushels to the acre, the average being just over 28. Oats cover a



MAIL TRAIN ASCENDING THE RIMUTAKA INCLINE, NEAR WELLINGTON

This incline, with a grade of 1 in 15, is constructed on the Fell third-rail system, and four or five engines in a single train are common.

slightly larger acreage, bearing an average of over 32 bushels and a maximum of 90. Barley is also cultivated to advantage. Potatoes are largely grown, the acreage under them and similar crops being over 320,000, and 7 to 10 tons per acre are frequently produced on suitable soils. Orchards cover 2,855 acres and gardens 4,727. Over a million and a half acres are ploughed and sown in grass and clover, and nearly 470,000 are surface-sown, while tussocks and native grass cover four million acres. Altogether, four and one-half million sheep, over 120,000 heads of cattle, 61,000 horses and 42,000 pigs are owned in Canterbury.

This is a record of what has been done in one of the nine provinces into which the Dominion is divided as the result of about sixty years' colonization. The factors which have ensured success in this one are present to almost the same extent in the others. Railways are being advanced inland in all parts of the country, and every year new lands are being thrown open. In this way millions of acres of previously unoccupied land in the heart of the North Island have only this year (1909) been rendered available for farming by the opening of a great trunk line of 500 miles between Auckland and Wellington. The soil is, for the most part, fertile, and covered at present with forest. The only preparation needed is the burning off of the timber, and the resultant ashes from this process furnish all the enrichment required to enable the best pasture grasses to grow and thrive when merely surface-sown, without any loosening of the ground. Often, within a year from this treatment, five to six sheep are being fattened per acre upon this land, while even the inferior soils will carry one sheep per acre, as a rule. The west coast of this island is specially suited for cattle, while in the midlands and on the east coast

long-wool sheep find congenial pasture.

Much of the new country is adapted for grain crops, though in places the soil is too rich for satisfactory growing, and enormous quantities of straw are produced without a corresponding yield of corn. Indian corn flourishes particularly, giving from 50 to 80 bushels to the acre. Potatoes also yield heavily when grown, as well as hops, sorghum, broom-corn, peanut, hemp, and China grass. Modern implements, such as the multiple-furrow plough and disc-harrow, are used throughout the Dominion and counteract the high price of labour.

Fruit is especially easy to grow, and in several districts a big canning industry is being worked up. All the British, Chinese and Japanese fruits, as well as oranges, lemons, limes, olives and grapes, are produced with the expenditure of just ordinary care. Hawke's Bay shares with Nelson, in the South Island, ideal conditions for successful orchards. Both have very high annual sunshine records, and both have rich soils and plenty of water. One orchard in Hawke's Bay has 150 acres in peaches alone. Auckland and Central Otago have also extensive orchards. A new departure is the cultivation of vines on a stretch of what was considered poor clay land about 50 miles south of Auckland City. Large quantities of table and wine grapes, of excellent quality, are produced in a yield equal to that of almost any vine country in the world. At the present time about 700 acres of vineyards exist in New Zealand, and there is, without any doubt, a good deal of money to be made by outdoor grape-growing in the warmer parts of the North Island. Some soils have recently been very favourably reported on for tobacco-growing, though up to the present little has been done in this direction.

One of New Zealand's distinctive

A TYPICAL NEW ZEALAND WATERFALL

Wairna Falls, used for logging Kauri timber, as shown in the picture.

crops deserves special mention. This is the rope-fibre generally known as New Zealand flax, the scientific name being Phormium tenax. It grows wild over most of the swamp lands of the Dominion, and till recently was simply cut from these natural growths, and no attempt was made to farm it. Lately, however, this has been done, and the Government are pounds' worth of fibre is exported per year from a total of about 250 mills.

From the soil, also, must be counted as originating the vast stores of timber waiting to be cut down. The chief wood is undoubtedly the kauri pine, from the Auckland province, a beautiful material, the supply of which is, unfortunately,

LOGS ON THEIR WAY TO THE SEA

making a systematic investigation into the cultivation of the plant. As a material for rope and twine the fibre is well known, but it has also been made into paper. Japan imports quantities of it, and there it has been made into imitation silk and lace. The treatment of the raw material, however, is yet in its infancy, and improved methods of growing and cleaning will much enhance the value of the industry in years to come. At the present time nearly a million diminishing only too fast under the great demand from all parts of the world. It is particularly useful for shipbuilding, and is one of the best carving woods in existence. Other timbers are the white pine, a soft and very easily worked white wood, though rather susceptible to rot. It is used for butter boxes and cases, and for purposes where great lightness is required. Totara pine possesses remarkable durability and resistance to weathering, rendering it

LOGS READY FOR THE DRIVE

ideal for piles, railway sleepers, etc. For brewers' vats it is said to have three times the life of English oak. As a wood-paving material it lasts well, wears down evenly, and has a non-slipping surface. Red pine, or rimu, is a hard and very ornamental wood, used for house-building and furniture-making. Black pine, or matai, resembles teak in many wavs, and is very stout and lasting. It is dense and smooth, has no tendency to shrink, stands exposure to damp to a remarkable degree, and being very close in the grain, is not readily worn by friction. Besides these, there are a series of mottled and figured timbers valuable as veneers and for purely ornamental purposes. At present about 450 timber mills produce about 340,000,000 feet annually. Large forests are awaiting the saw, particularly in the newly opened-up lands in the North Island. Much of the area thus covered is immediately required for settlement, and, when the trees are small, the rapid but wasteful process of burning is resorted to.

One example of huge resources of timber awaiting exploitation in this district may be quoted. On a plateau about 2,500 feet above the sea, beside the new railway, occurs a forest, estimated by the Crown Lands' Commissioner as covering 151,200 acres, of which 72,700 belongs to the Government. The quantity of milling timber, according to the same authority, totals 1,058,400,000 feet, which the Land's Department calculate will produce £8,000,000 in royalties alone. A number of mills have already begun work on the fringe of this big forest. This is one instance only of the supplies of timber ready for development, for almost the whole of the unoccupied country is covered with 'bush," to give it the local name. The Government proposes setting apart up to 50,000 acres of rough forest-country for establishing the industry of pulp manufacture for paper-making. Leases of such areas, up to 30,000 acres, may be granted for twenty-one years.

IN THE FORESTS OF NEW ZEALAND

TIPPING A LOG DAM ON A NEW ZEALAND STREAM

Depending upon the soil is also the woollen industry, which, of course, goes hand-in-hand with the production of mutton. As has been already said, New Zealand relies most largely upon its pastoral country for its annual income. The sheep-farmer has much in his favour—abundance of feed and water throughout the year and suitability of climate and soil. Almost every kind of sheep does well, from the merino to the Lincoln and Leicester, thanks to the variety of conditions. There are low, moist lands near the sea-coast, and tussock-covered mountain slopes, with all the intervening grades. On the former Lincoln and Romney marsh sheep thrive especially, while on the upper and drier lands Border Leicesters and Downs are bred. The merino finds remarkably congenial pasture on the hills and ranges of the South Island, right up to the snow-line of the Alps. One great feature of the industry is the large lambing yield, which enables New Zealand farmers to export about a quarter of their flocks annually without decreasing the total number. Nearly £3,000,000 worth of frozen mutton and lamb is exported per annum, while the meat-canning industry is rapidly growing, and has reached a present value of over £100,000 a year.

The absence of droughts ensures a uniformly good staple of wool, free from the breaks and other imperfections common in less favoured countries. The material produced is partly exported in the raw state and partly made up in the Dominion. Over seven and a half million pounds' worth of wool was exported in 1907, while much was used locally in the ten woollen mills situated principally in the South Island. Extensive as the sheep industry is, there is room for very large increase in the near future. The newer districts in the centre of the North Island are particularly adapted for small and moderate-sized holdings and for mixed farming. The North Auckland penin-

sula, possessing a warm and mild climate, is holding out splendid prospects for such farmers, its inaccessibility having retarded its development until quite lately.

These new lands in particular offer opportunities for the dairy-farmer. At present there are about 270 butter and cheese factories in the country, of which the great majority are in the North Island. The value of the last recorded output was over £2,000,000. The Government are at present setting up a Dairying Institute, where their experts will conduct experiments with a view to assisting farmers in improving the quality of their produce. In common with other branches of farming, every use is made of modern machinery, and milking machines are the rule in large establishments. A typical instance is the case of a farm in North Otago, where 150 cows are milked by a suction machine driven by a 6 horse-power oil engine, which also operates chaff-cutters and other utensils. Quite a number of farms have hydro-electric installations for light and power.

Specially suitable for dairying is a big tract known as the Piako swamp, in the south of Auckland, which is at present being drained by the Government. About a million acres will be affected, and will be turned into rich dairying and agricultural land.

The chief districts suitable for farming are those containing the mineral wealth of the Dominion. Reference has already been made to the great diversity of these products, most of which are yet awaiting capital and enterprise for their development. The chief, almost the only deposits, at present extensively worked are gold, silver and coal. The last-named is almost entirely mined for home consumption, and as it is used to such a large extent in other industries, and is of such vital importance for commerce generally, I shall deal with its occurrence first.

A SHEEP STATION NEAR MASTERTON, WELLINGTON PROVINCE

Coal is obtained in many parts of New Zealand, but the chief mines are in the Westport district, in South Nelson; the Grey district, in Westland; in Otago and Auckland. The best coals occur in the two former, the Westport mines producing a quality scarcely equaled throughout the world. This is described as a steam coal, with the following typical composition:

VIEW AT THE WEEKLY SHEEP SALE AT MASTERTON, WELLINGTON PROVINCE

Fixed carbon	56.47
Hydrocarbon	38.78
Water	4.00
Ash	.75
	100.00
Total sulphur	1.00

Six hundred and fifty thousand tons of this coal were mined in 1907, and the total is increasing rapidly as new fields are opened up. At the end of 1908 the Westport-Stockton Company began work with an electric plant capable of furnishing 100 tons per day. Like many other west coast mines, this one is situated 2,000 feet above the sea, though this disadvantage is minimized by electric tramways and endless-rope inclines controlled by modern hydraulic brakes. The supply is abundant and uniformly good, and cutting is easy and safe. Large areas containing thick seams of the same coal are untouched in the vicinity of the mines at present being worked. The British Admiralty are customers of this coal, and have been since before the days of the *Calliope*, which made her famous exit from Apia harbour burning Westport fuel.

About a hundred miles further south is another excellent coal field, of which the chief town is Greymouth. There are six seams in this mine, which has not yet started work (September, 1909), aggregating 63 feet in thickness. The quality of the coal is first-class, as is seen from the following table, giving the results of the analysis of a sample taken from the property of the Paparoa Company. This sample was derived from one of the two lowest seams, which

are classed as anthracites, while the others are more of a bituminous nature.

Fixed carbon	80.25
Hydrocarbon	15.10
Water	0.65
Ash	4.20
	100.20
Total sulphur	0.37

Last year nearly 400,000 tons were obtained from the Grey district.

Besides these, mines in Otago produce good coal totalling nearly 450,000 tons per annum, and from Auckland about 190,000 tons are obtained.

The mining of gold dates from a very early epoch in the history of New Zealand. It was in 1852 that the first patch was struck in the Auckland province, and since then many fortunes have been made in the Dominion. In 1907 over £2,000,000 worth of gold was exported, of which more than half comes from Auckland. The rest is derived from two other gold-producing areas—Westland and Otago. In the north the metal is extracted by quartz-mining solely, while in the two southern fields alluvial mining and dredging are also utilized. By far the best property is the famous Waihi mine, in the Ohinemuri hills of Auckland, which yields steadily about £70,000 worth per month. Adjoining Waihi is the Karangahake district, with many wealthy claims, of which the Talisman, producing £184,445 in 1907, and the N. Z. Crown Mines, producing £57,242, are the most important. The Komata Reefs Company yielded £47,128, and the Thames district, in the same neighbourhood, contains a number of mines that have produced phenomenally rich yields. The Waiotaki gave £149,833 in 1907, and besides this there are the May Queen, Kuranui-Caledonian and others. In the south gold-winning is being proceeded with vigorously in Westland, where ad-

GOLD DREDGING IN CROMWELL, CENTRAL OTAGO

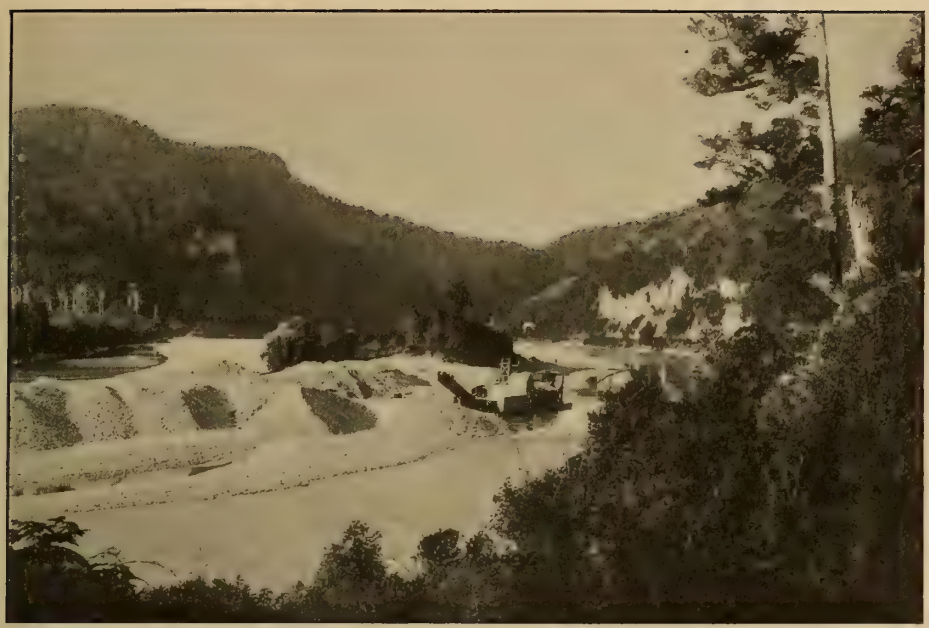
vances are being made just at present. The Progress Mine, and the Keep-it-Dark, at Reefton, are the chief quartz-mines, the former giving £87,805 worth in 1907. The Mont d'Or claim, at Ross, is an extensive sluicing property, while gold is obtained from the rivers of this district and of Otago by means of 165 dredges. The Clutha River, in the southern province, is a huge natural sluice-box and the scene of great dredging industry. A total value of

GOLD SLUICING AT ROSS, SOUTH WESTLAND

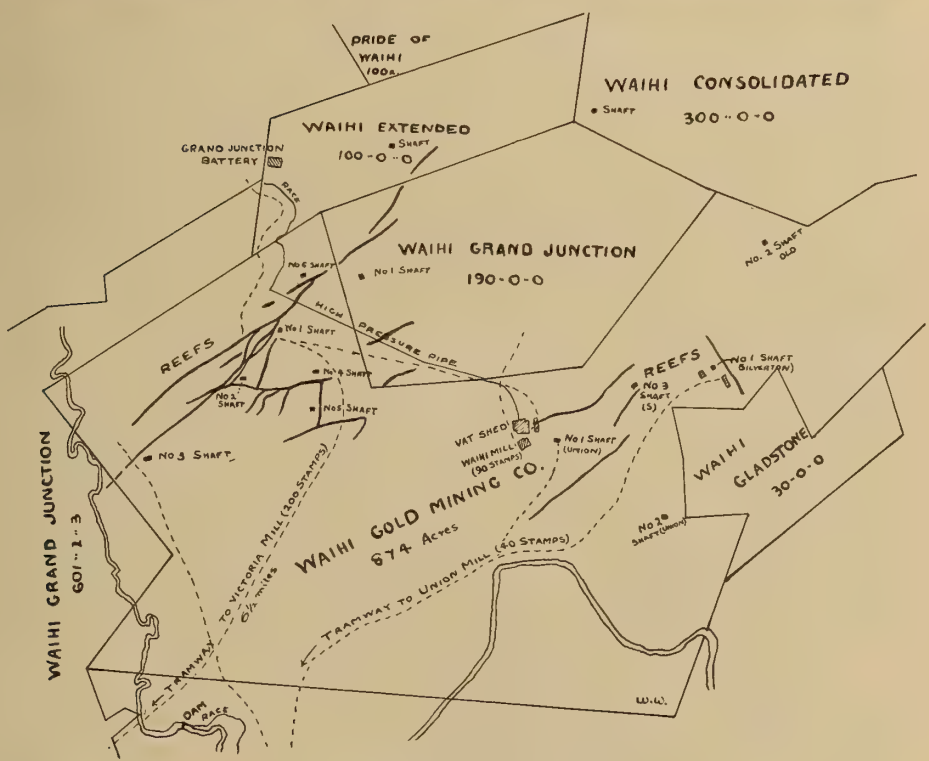
£620,900, mostly obtained from dredges and small sluicing claims, came from Otago and £381,874 from Westland in the same period.

With regard to future extensions of the industry, there is every evidence of abundance of metal untouched. This is particularly the case in Auckland, as will be seen when an inspection of the existing sites is made. At Waihi there is much country of great promise adjoining the Waihi Gold Company's mine. This enterprise is famous throughout the world for its productiveness, as a venture which steadily pays dividends of 85 and 90 per cent. deserves to be. Its success has been due to the discovery of the cyanide process for treating low-grade ores, a method originating from this country. A map of the region is shown, and it will be seen that every indication points to the rich reefs extending into the adjoining properties, notably the Waihi Grand Junction. The investment of more capital in the near future will almost certainly prove this to be the case. At the Thames new extensions are about to be made beneath the present levels. Up till now the workings have been comparatively shallow, as it was believed that gold could not exist at a depth of 1,000 feet.

However, good metal is now obtained at Bendigo, in Victoria, at depths of 3,000 and 4,000 feet, and at Reefton, in Westland, the Wealth of Nations Company obtain good ore at a depth of 1,775 feet, and are at present sinking to a further depth of 125 feet. The formation of the



A GOLD DREDGE IN THE BULLER GORGE, NEAR WESTPORT



MAP OF THE WAIHI GOLD-MINING DISTRICT

ASCENT INTO WESTFORK STOCKTON MINE

COAL MINE AT BRUNNER, WESTLAND, ON THE GREY RIVER

Thames reefs indicates their presence at greater depths, and though want of capital is checking enterprise at present, there should be a great future before the Thames Deep Levels.

In Westland growing enterprise is accomplishing good results. The whole province is a proclaimed goldfield, and much gold exists that yet awaits working. Only this month (September, 1909) a hydro-electric plant of 2,000 horse-power has started work at Ross, and by expelling water from flooded workings is about to reap its harvest. In Otago gold is produced over a wide area, and is worked almost entirely by dredging and sluicing. The total production is high, but the prospects of extensions are not so bright as in the northern fields.

Silver is found accompanying gold in many places, such as Waihi. In 1907 over a million and a half ounces were mined. Copper occurs in thirty-one known localities altogether but is richest in Nelson and Auckland. Small quantities have been worked at various times, such as 351 tons in 1858 and 245 tons in 1859; but for want of systematic prospecting, not sufficient ore has been developed to warrant extensive outlay. A heavy lode of copper pyrites, with native metal, is at the present time being worked near Nelson City, and a syndicate has just begun smelting operations in Auckland.

TRANSPORTING TIMBERS THROUGH FOREST OF NEW ZEALAND

What may become one of the most valuable resources in New Zealand is the supply of iron ore. This consists of two varieties, the Taranaki ironsand and the Parapara deposits, in the Nelson district. The former is

a black, titaniferous, magnetic ore, present in inexhaustible quantities on the sea shore. Owing to its finely-divided condition, smelting by existing processes has not been commercially possible, although briquetting was tried for some years. A successful modification is being keenly sought for, and, indeed, a new local method is said to be about to solve the problem. Quantities have been exported to Germany for reduction by the electrolytic process, for which are at present worked to any extent.

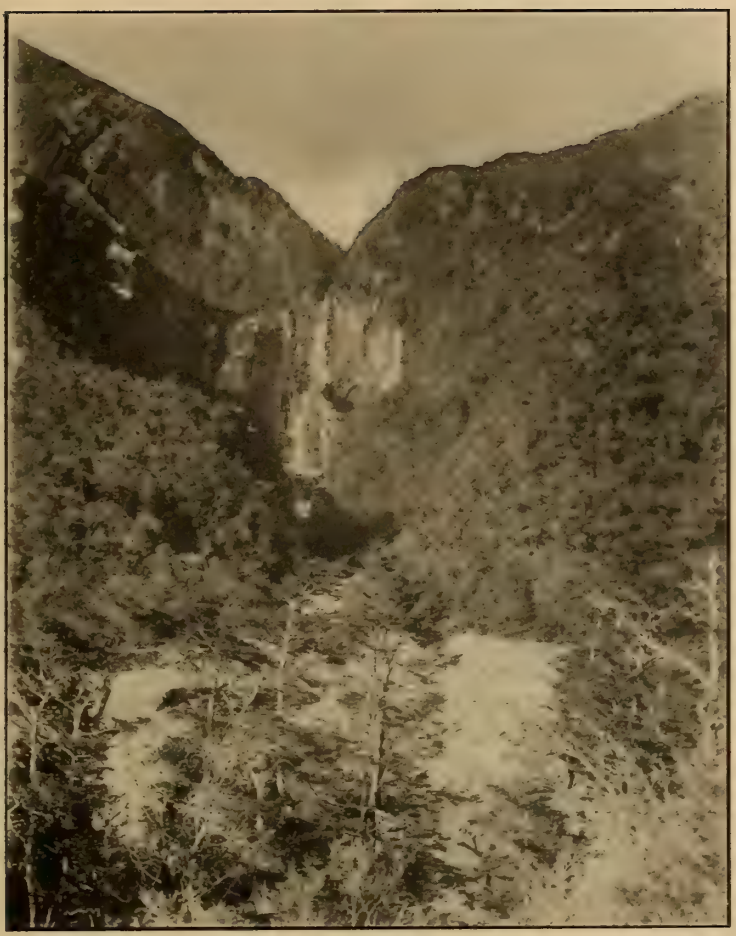
Besides these minerals, the chief others known to exist are mercury (cinnabar), platinum, nickel, lead, tin, zinc, antimony, arsenic, manganese, chromium, osmium, iridium, tellurium, titanium, tungsten and petroleum. The last-named is being worked by small companies in Taranaki and at Kotuku, in Westland, while tungsten is found as scheelite in considerable quantities in Otago. The available ore in the two reefs

MOTOR TRAWLING IN NEW ZEALAND

this ore is exactly suited. The latter deposit is a comparatively recent discovery in the Nelson province, existing in the form of a stratum 100 feet thick, exposed over several acres. It is under half a mile from the sea-front, and is in the immediate vicinity of coal, limestone and water-power, so that it would seem to be a particularly desirable proposition. The ore is pure hematite mixed with quartz pebbles, and contains 40 per cent. of iron. Nine other fairly large deposits of iron are known and none being worked is estimated at 60,000 tons. It is being shipped to Europe, where it is used for the manufacture of high-grade steels. The export for 1907 totalled 137 tons, valued at £15,486.

A unique vegetable deposit exists in the form of kauri-gum, the fossil resin of the kauri tree. About 3,000 diggers find employment in obtaining this substance and preparing it for the market. It is exported chiefly for the manufacture of varnish.

Building stones are fairly plentiful



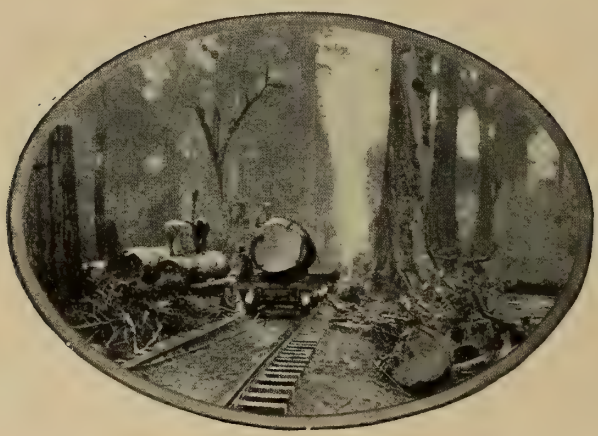
A NEW ZEALAND HYDRAULIC POWER SITE

in New Zealand. Limestones are found in various localities; but the chief supply comes from Oamaru, in North Otago. The stone is very easily worked, has a beautiful white colour, and has good weathering qualities when properly hewn. Harder varieties come from South Canterbury. Volcanic remains all over the country yield excellent blue and black basalts and dolerites. Granites of great beauty are common in Westland and the North Island, and marble of several varieties has been recently discovered in Hawke's Bay, probably in large quantities. Sandstones are rare.

One of the most valuable assets of the Dominion as a potential manufacturing country is the enormous supply of water-power. Nearly all the rivers are really large cataracts, owing to the short distance between the sources in the high mountains and the sea. Waterfalls are common, and are being increasingly harnessed for power purposes. Dunedin City, to quote one instance, is lit, and has its trams and factories operated, by electric power from the Waipori Falls, under 40 miles distant. There is a proposal to similarly supply Christchurch, the capital city of Canterbury, with 5,000

horse-power from the Waimakariri River, about the same distance away. Many smaller places have obtained power almost at their doors. Altogether, about 4,000,000 horse-power is readily available, though far more could be obtained if necessary.

This completes the list of the chief resources of New Zealand. It is a small country, and one cannot expect its products to be on the big scale met with in such a land as America. However, for its size, it has a productiveness probably unequaled anywhere, as those readers who have taken the trouble to follow the above statistics will admit. The principal authority throughout the article has been the Official Year Book of the N. Z. Government for 1908, which has been resorted to whenever figures were required. To this volume those desirous of more detailed statistics are referred.



ENGINEERING AND ART

By Julian Chase Smallwood

IN this busy age of industry and greed we are all liberally tarred with the stick of commercialism. It tinctures our acts and judgments, and all but blinds us to the fact that we have time for anything but business. Literature is closed to us—we have no time for idle reading of books. On the rare occasions when the successful business man surrenders himself to the opera or art gallery he consoles himself with the reflection that his social advancement may be converted into dollars and cents, and thus his time may not be wholly lost. Sometimes he makes art his hobby, and then his valuation of the beautiful is based upon the existing amount of it and the prominence given him if he secures it. But there is not, and never can be, thinks he, any direct connection between art and money-getting.

If this is true of those engaged in trade, is it more or less true of us engineers whose vocation is, it has been said, to make one dollar do the work of two? I can imagine one answering, "My part in life is economic production—it is another's part to paint pictures, to compose music, or to make poetry. We each supply a want of humanity—I supply a need. Then should I depart from my way to dabble in the work which is not mine, especially as the outcome only furnishes the relaxation which may be pleasant to others but not to me? My relaxation is the pursuit of science—what will art avail me?" Doubtless it will be believed that this view is typical of engineers who are truly enthusiastic in their work. Aside from this singleness of interest, the very nature of engineering inclines us toward the mundane. We who are practising our profession have it forced in upon us from start to finish that the Almighty Dollar is the most potent factor figuring in the denominator of all fractions expressing efficiency. Our sensibilities are burdened beyond their strength with this weight of the dollar. It is not our business to build an engine that will deliver the highest horse-power-hours per pound of steam, but we must construct such a one as to yield the maximum work for the dollar expended. The goddess Efficiency sinks into insignificance beside the glory of her sister, Economy. None disputes that the Economy has superior charms, and is worthy of the worship accorded her. The fault lies in us rather than her, that we cannot pay her homage without being dazzled by her brilliance. And thus we lose sight of the fact that there are other goddesses the worship of whom is merited and wise. So the engineer asks in his simplicity, "Of what avail is art to me?" I answer, "If you make some sacrifices at the altar of art they will soon cease to be sacrifices, and at the same time Economy's beneficence will be increased."

I can imagine you, busy man of science, turning over the page with a sneer, saying, "Art and engineering—yes, Kipling has coupled them; but I cannot see that engineering is any the better for it." Have you ever considered that peculiar anomaly of banker and poet, Clarence Sted-

man? Have you ever reflected upon the talents of that friend of story-lovers, F. Hopkinson Smith, who is at once a novelist, a painter and an engineer? Have you ever thought of that master of English letters who could produce "The Raven," in spite of the possession of one of the keenest mathematical minds of his generation? Have you ever been informed that a clergyman named Charles Lutwidge Dodgson, a brilliant writer and lecturer on mathematics, has furnished a pleasure to your children which you have never given them, and will do so to generations of little ones to come, by his creation of "Alice in Wonderland"? Do you remember reading in your school-boy history about one Benjamin Franklin, whose homely inventions and tremendous scientific discoveries live and are useful to-day, side by side with his Poor Richard's Almanac? You know of his illustrious name in science—do you know his achievements in letters? Consider these famous men and many more like them, then ask yourself, "Is there any tangible connection between art and science?" "Doubtless," you will say, "a man may have artistic as well as scientific accomplishments." I reply that these men were better scientists *because* they were artists, and that *you* will be if you cultivate anything that may be artistic in you. The magnificent City of Engineering has a broad road traversing it and leading into the beautiful Country of Art—the road of Imagination. If we labour on without following this road, we are as children of the alleys who do not know the inspiring sunshine. Our vision, then, is limited by the dull walls we see before us; we cannot create glorious new structures, because our minds can conceive of nothing that our eyes do not see; and our life-work consists only of a maintenance of the structure built by those who have confined themselves before us in that narrow way.

Men of science, your faculties are weakened by the very exactitude which is your pride. You measure and weigh, and you are surrounded and overwhelmed by the limitations imposed by the experiences of your senses. You seek causes upon observing effects, or determine the effects resulting from given causes; but such analyses do not lead you into the realm of imagination. You are too material. If you had been Newton upon observing the apple fall, you would have thought, "The reason why it fell was because its stem became too weak to hold it." Newton, however, had an imagination, and thereby he discovered the law of gravitation. Columbus did not care to prove simply that the earth was round. His imagination fired him with a knowledge of benefits to mankind resulting from a possible (and, as it turned out, chimerical) northwest passage due to such roundness. His imagination inspired the discovery of a continent. And so it is with name after name in history, and so it will be with you and me. We may achieve some small measure of success by doing what our fathers did before us, but our really big deeds will be offspring of our imaginations. Sometimes we see inventions accomplished by chance or a benefit opened to mankind by a stumbling footstep. Such are rare, and shiftless we should be did we count upon circumstance for success. Nor would very much credit be attached to us for such accomplishment. The man who discovered gold in California shook the continent, but his name is now almost forgotten.

Does it not become apparent that without the stimulus of imagination science becomes as unproductive as a tree which puts forth only leaves when it might bear fruit? I would put it even more strongly. Science is but a servant of the imagination. Euclid built his geometry theorem upon theorem, and his science served his imagination to create a new structure. The delightful imagination that conceived "Alice in Wonder-

land" was the attribute that made the scientist in its author capable of grasping that zero divided by zero equals a finite quantity. And no one can deal with mathematics understandingly who does not allow this quality of his mind full play. When we deal with infinity in the science of generic members; when we speak of lines of force in electricity; when we consider atoms in chemistry or entropy in thermodynamics, we step at once into the domain of imagination. The senses cannot grasp these things; how, then, can we even remotely conceive them without employing the imagination? Have you ever stopped to think of what audacious conceptions your daily work is based upon? What a fanciful thing is a logarithm! obtained by multiplying a number by itself a fractional number of times. What a commonplace figure is π, and yet how absolutely impossible to grasp! How wonderful that the calculus enables us to obtain in one minute a result whose arithmetical computation would last for infinity! If you use these things without reflecting upon the wonder of them, you will be as a man who guides an automaton that turns bone into buttons and takes interest in naught but the raw material and the product. Should he, however, possess that ability which I am disposed to exalt, it would lead him to consider thus: "The steps in this transformation are as I see them. If this step could be omitted, and that one combined with another, what a saving there would be! The machine will do more work in a given time, will be simpler, and will, therefore, cost less. Perhaps I can accomplish it." And here his mind may finish the imaginative work it has begun. Franklin did but the same when he first conceived and then confirmed the identity of lightning and electricity.

We are all born with some of this divine fire of imagination. We see it in all children; but, alas! it too often sinks into desuetude with the passage of childhood. Can you give it new life? Yes, undoubtedly. No matter what your years, nor how mundane have become your views of life and work, you still have the power of developing it. The phenomenon is of daily occurrence. A new interest, a new hope or faith, kindles the fire, and we again live in the realm of imagination—for a time. We can always, with the will, cause this spark to flame. And I think that that which is most conducive to its development is a lively appreciation of wholesome literature, the appreciation of which may be acquired by anyone whose intelligence entitles him to the name of engineer. Books are ever-ready and ever-faithful friends. When I think of the thousands that have been, and will be, intellectually nourished, as well as entertained, and, therefore, strengthened for their work, by such a man as Thackeray, I feel that he and such as he are among the first benefactors of the human race. Do not turn away from them saying you have no time for such pastimes. You have time for anything you earnestly want to do. *Want* to do this. Do not deprive your imaginations of such a stimulus. If you read a poem such as the "Ancient Mariner," picture after picture will flash before your mind—the wonder of Coleridge's words is that they cause this active working of the imagination. Such a mental exercise cannot fail to make vigorous that attribute of the mind, no matter how dormant, which is so essential to a broadening of our scope of usefulness.

In the foregoing I have sought to point out that the engineer's inclinations and vocation cause him to ignore the creations generalized under the name of art; that such ignorance deprives him not only of a vast pleasure, but a positive benefit; and that he actually needs this benefit in his daily work. If it is acknowledged that imagination is essential to science, the appreciation of it will result in a new perception, a new

perspective, and a scope at present beyond his ken. His conceptions of the real combined with the unrealized will be the embryo of an ideal fulfillment.

And these selective and constructive conceptions will be born of the only mother who can bear them, which perhaps he, with others, has scorned—the mother Imagination.

CRANES AND HOISTING MACHINERY—II.

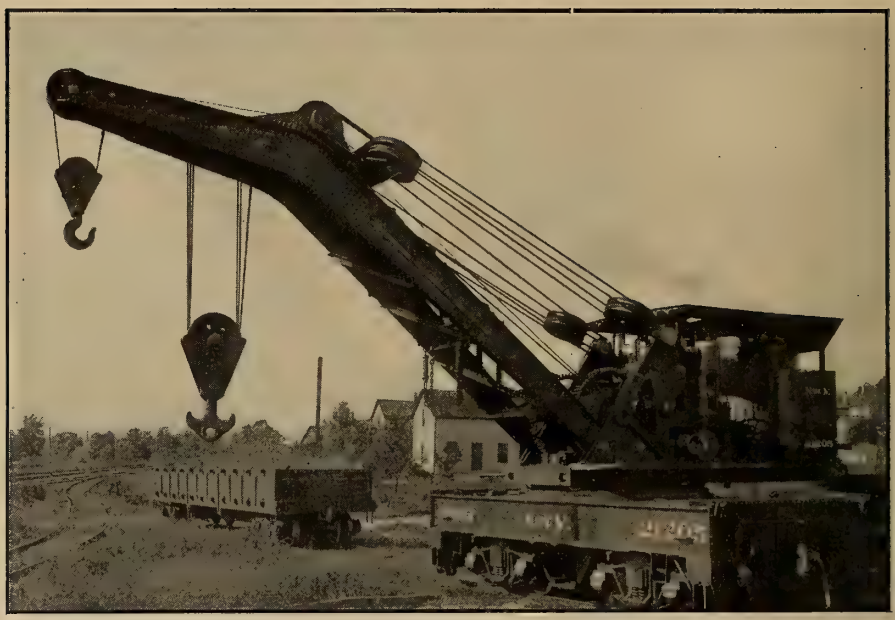
By J. F. Springer

AMERICAN LOCOMOTIVE CRANES

THE locomotive crane is one of the most useful of the many types. It runs on a railway track, usually of the ordinary gauge; but sometimes this gauge is widened to secure greater stability. Such a crane, proceeding under its own power, is a wonderfully complete piece of apparatus. There is usually, if not always, a central pin about which the crane-jib, together with the lifting and rotating mechanism, is free to rotate. If additional weight is needed for counterbalancing, it is placed upon the rotatable platform. Such cranes usually are operated by steam.

Among the illustrations is shown a locomotive crane made by the Browning Engineering Company, of Cleveland, Ohio, which is a fine example of an all-steel type of construction. The steel car, supported

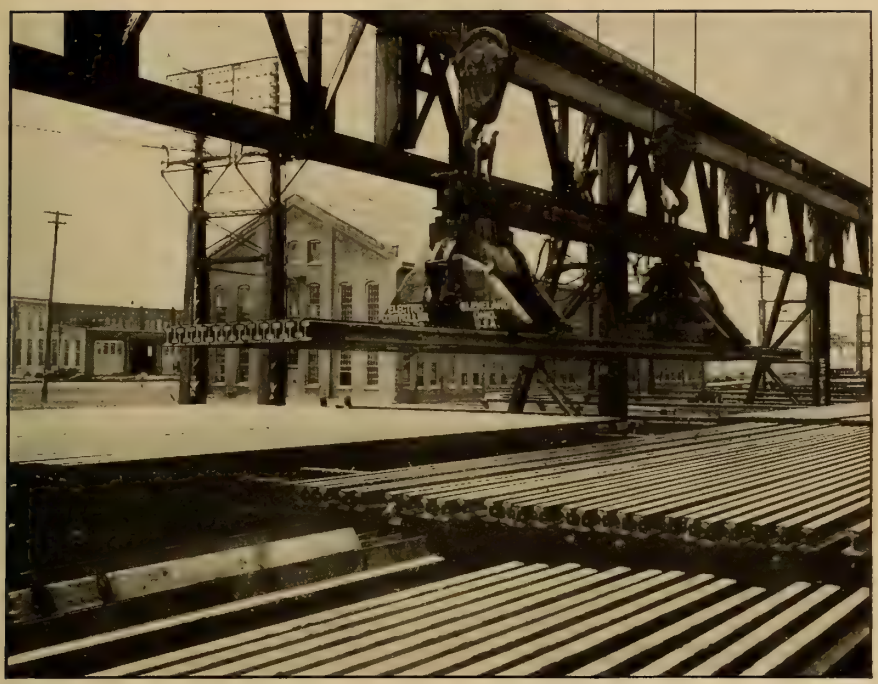
BUCYRUS WRECKING CRANE IN ACTION



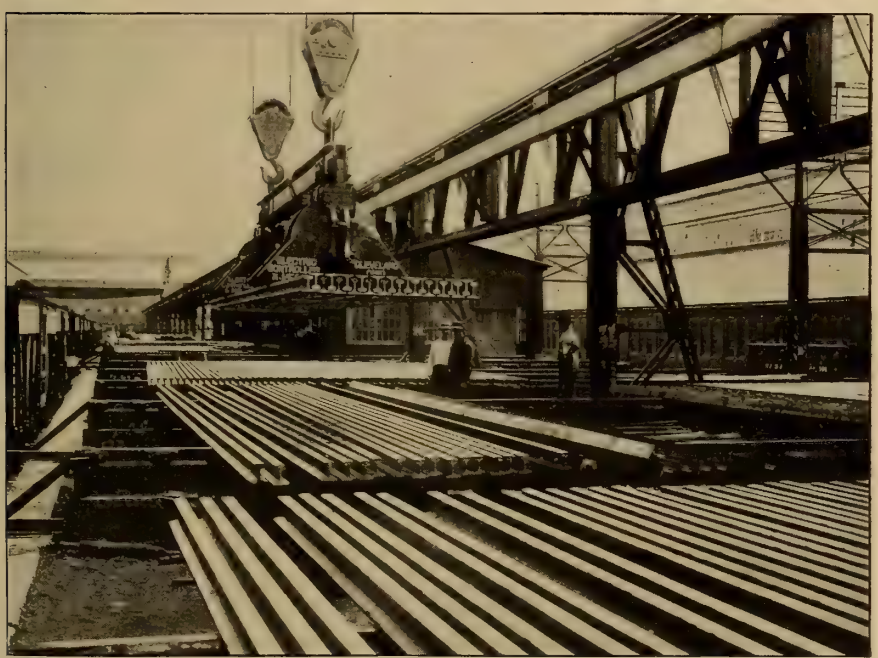
LOCOMOTIVE CRANE. BROWNING ENGINEERING COMPANY, CLEVELAND, OHIO

by eight wheels, and the steel jib, formed of a bent A-frame latticed above and below, give evidence of heavy construction. There are two blocks, the inner one having three sheaves. It will thus be seen that the

ALL-STEEL LOCOMOTIVE CRANE. BROWN HOISTING MACHINERY COMPANY, CLEVELAND, OHIO



MAGNETS HANDLING RAILS AT GARY, IND. ELECTRIC CONTROLLER & MANUFACTURING COMPANY, CLEVELAND, OHIO



MAGNETS HANDLING A LOCKED SECTION OF RAILS AT GARY, IND. ELECTRIC CONTROLLER & MANUFACTURING COMPANY, CLEVELAND, OHIO

Lifts are from 10 to 12 tons

LOCOMOTIVE CRANE. WELLMAN-SEAVER-MORGAN COMPANY, CLEVELAND, OHIO

crane is a combination of a machine capable of light work at a considerable radius and of heavy work at a more reduced compass.

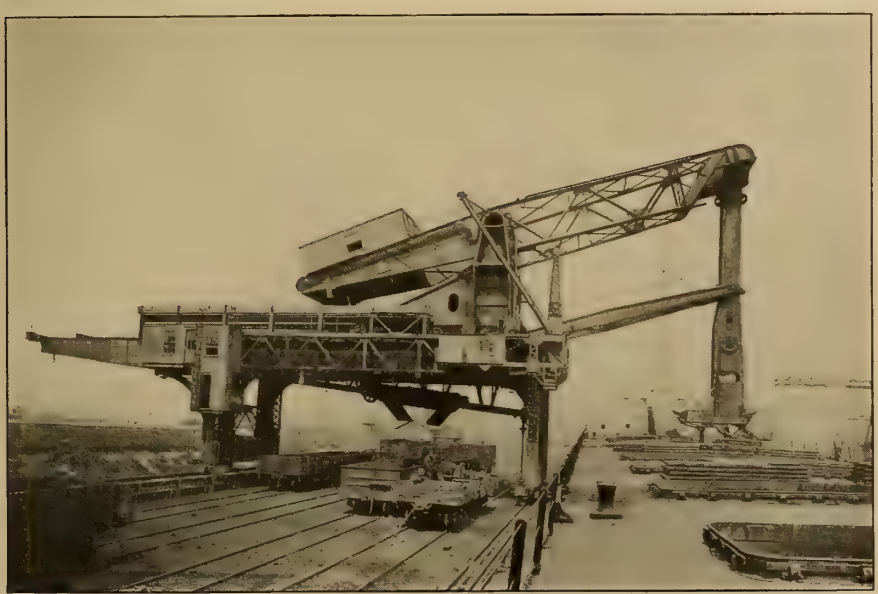
Another interesting locomotive crane is a product of the Wellman-Seaver-Morgan Company, of Cleveland, Ohio. This type is adapted for light and rapid work. The long steel jib, half latticed on each side, gives an impression of strength and lightness. The grab-bucket enables it to perform a variety of service in loading with coal, in removing ashes, and the like.

An example of all-steel crane construction is the machine built by the Brown Hoisting Machinery Company, of Cleveland, Ohio. The jib of steel lattice-work is both light

LOCOMOTIVE CRANE. INTERSTATE ENGINEERING COMPANY, NEW YORK

and strong, and gives a long radius of action. The attachment of a lifting magnet is coming into quite common use. That the combination of locomotive crane and magnet makes a very effective apparatus for the handling of pig-iron will be seen from the illustration on page 218.

One of the most notable examples of the use of lifting magnets appears in connection with the operation of the rail mill at the new plant of the United States Steel Corporation at Gary, Ind. The machinery of these



ELECTRICALLY OPERATED HULETT UNLOADER

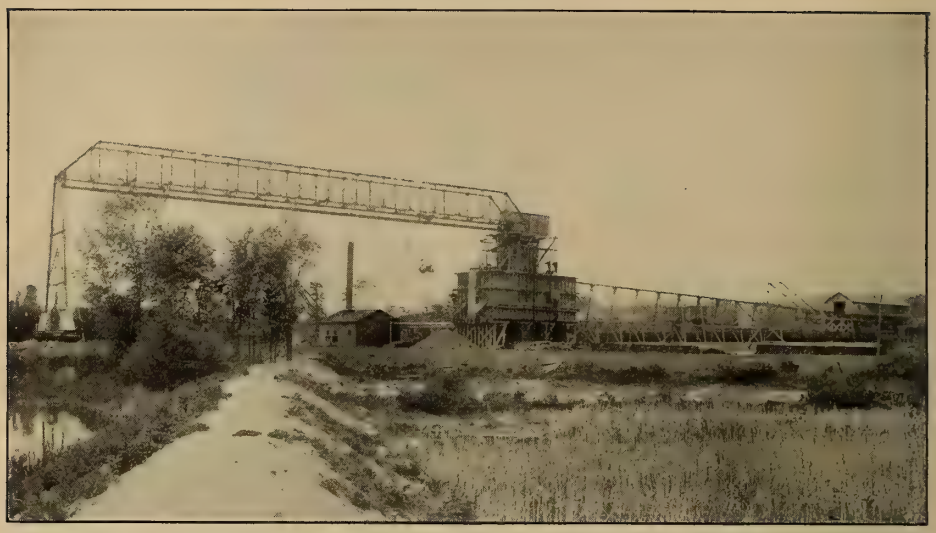
COALING A LOCOMOTIVE. MC MYLER MANUFACTURING COMPANY, CLEVELAND, OHIO

mills is operated almost wholly by electricity, and hence there is abundant opportunity to install lifting magnets. The illustrations show the use of magnets for handling steel rails in locked sections, a difficult

LOCOMOTIVE CRANE UNDER TEST. BUCYRUS COMPANY, SOUTH MILWAUKEE, WIS.

LOCOMOTIVE CRANE. BROWNING ENGINEERING COMPANY, CLEVELAND, OHIO

TRAVELING BRIDGE CRANE. MC MYLER MANUFACTURING COMPANY, CLEVELAND, OHIO



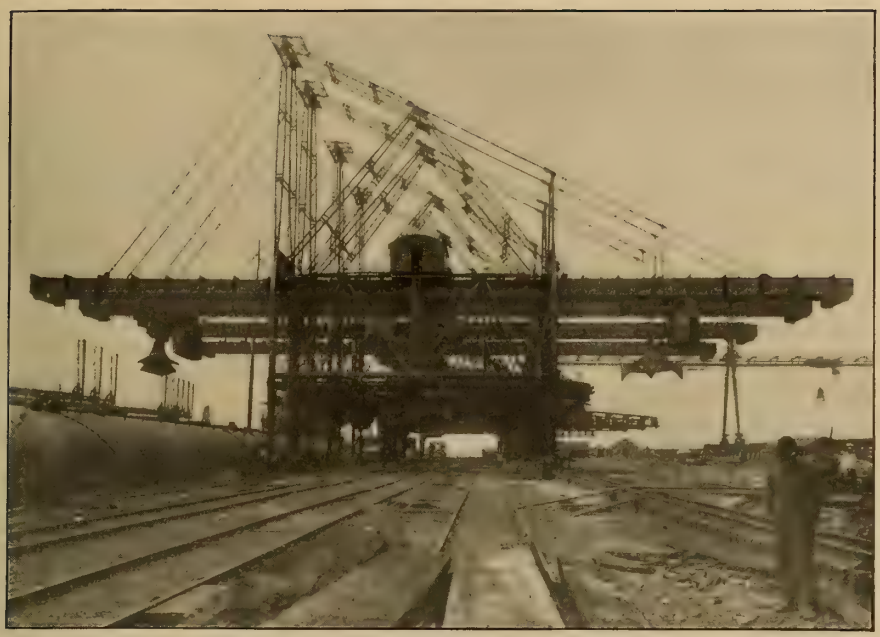
COALING BRIDGE AND RAILWAY. C. W. HUNT COMPANY, NEW YORK

operation unless the apparatus is powerful and correctly designed, since the top layer of rails practically short-circuits the magnetic field and prevents the attraction from reaching the bottom layer.

The magnets used at Gary were designed and constructed by the Electric Controller & Manufacturing Company, of Cleveland, and have proved very successful in operation. They have lifted not only locked sections of 33-foot rails, but have also lifted successfully locked sections of 60-foot rails, with an aggregate load of 60 tons.

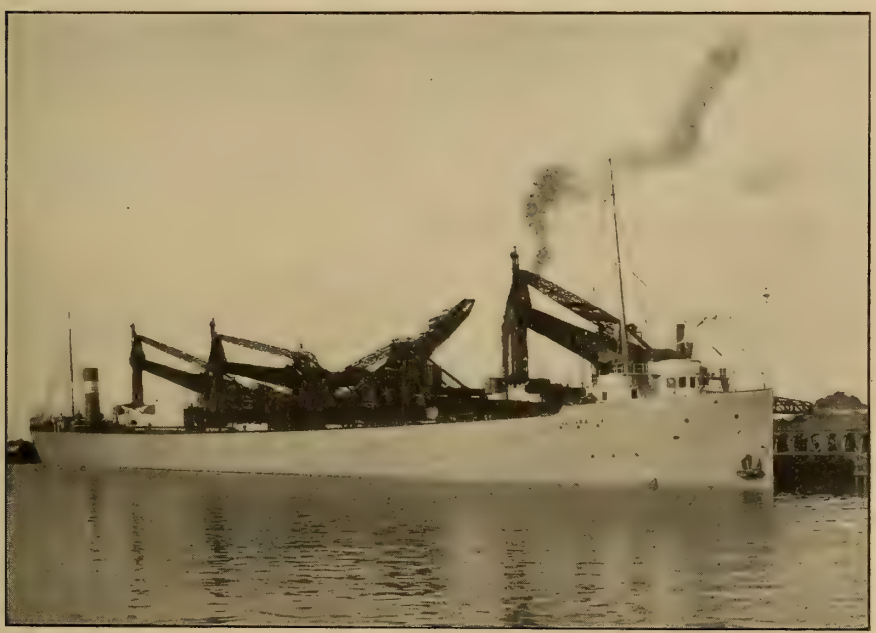
The locomotive crane is, of course, well suited to wrecking apparatus along railways. The illustration shows an example of an all-steel type built by the Bucyrus Company, of South Milwaukee, Wis. That this is an exceedingly powerful piece of apparatus may be seen from the load of 100 tons. As a lifter, this crane belongs in the class with the great floating cranes of the New York Navy Yard and of Buenos Ayres.

TRAVELING BRIDGE CRANE. MC MYLER MANUFACTURING COMPANY, CLEVELAND, OHIO



LOCOMOTIVE CRANE OF THE BRIDGE TYPE. BROWN HOISTING MACHINERY COMPANY, CLEVELAND, OHIO

But, of course, its radius of action is short. An example of a Bucyrus wrecking crane actually engaged in the performance of its duty is to be observed in the photograph of a crane lifting a wrecked engine.



FOUR HULETT UNLOADERS AT CONNEAUT, OHIO

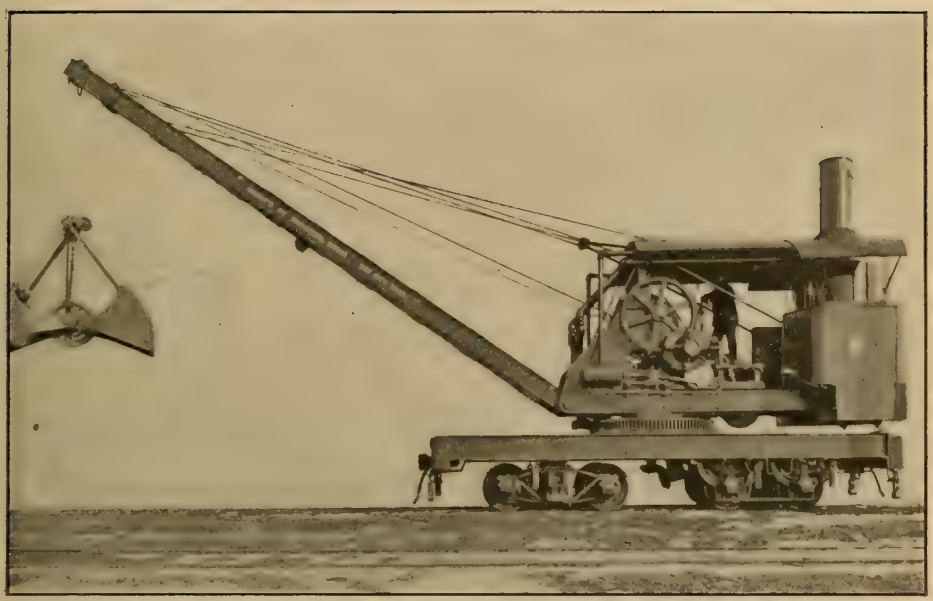
10-TON LOCOMOTIVE CRANE EQUIPPED WITH LIFTING MAGNET. INDUSTRIAL WORKS, BAY CITY, MICH.

That the field of usefulness of the locomotive crane is quite a wide one is still further manifested by its application to work in scrap yards, and the illustration shows a crane built by the Interstate Engineering Company, of Cleveland, Ohio, in operation in one of the largest of these yards.

The adaptability of this style of crane for the purpose of coaling locomotives is well illustrated. With the coal car on one side and the tender of the locomotive on the other, this crane, built by the McMyler Manufacturing Company, of Cleveland, Ohio, is performing a necessary service in a very economical manner.

We have a somewhat unusual type of what is, in effect, a locomotive crane mounted on a float. Fitted with a clamshell grab-bucket, such cranes are well adapted to perform dredging service. This is also a McMyler product.

Another unusual type is also built by the McMyler Company. The bridge straddles the railway track and permits the passage of trains



LOCOMOTIVE COALING CRANE HANDLING 2-CUBIC YARD BUCKET. INDUSTRIAL WORKS, BAY CITY, MICH.
Capacity 25 tons

TRAVELING CRANE AT CONNEAUT, OHIO. BROWN HOISTING MACHINERY COMPANY, CLEVELAND, OHIO

MC MYLER LOCOMOTIVE CRANE MOUNTED ON FLOAT

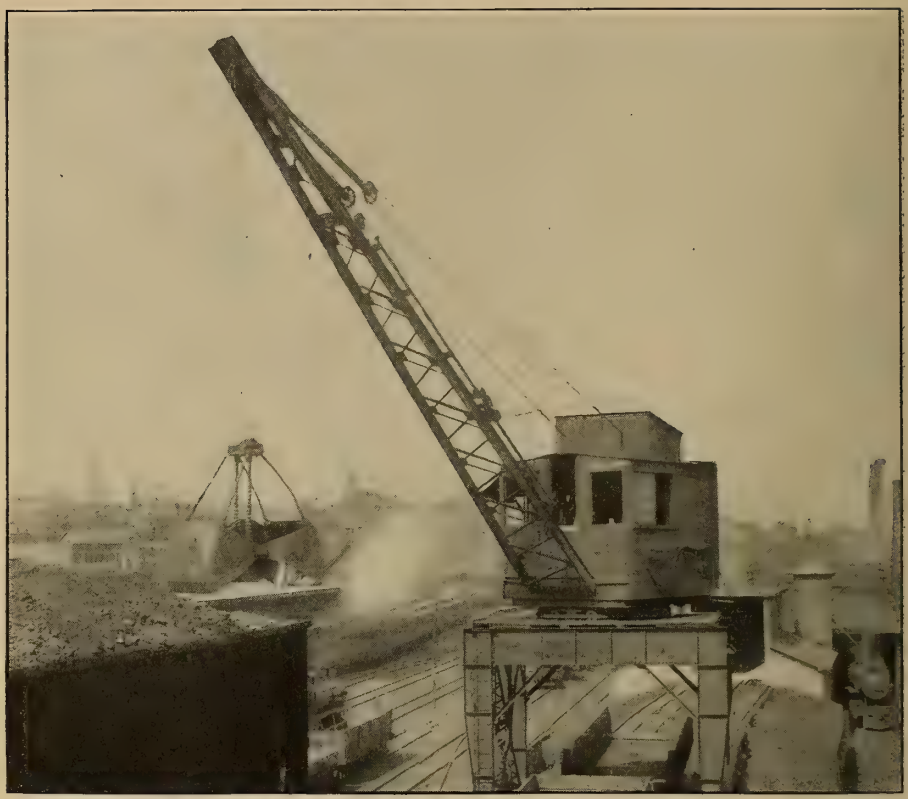
during the operation of the crane. The grab-bucket is of the clamshell type. All operations are controlled from the cab; that is to say, the movement of the jib, that of the grab-bucket, the rotation of the cab, together with the jib, on a vertical axis, and the transversing movement of the entire apparatus upon its own special track, are all commanded from the operating cab. The transversing movement is effected by means of shafts and bevel gears, arranged to transmit the drive down the axis of rotation of the cab, across the bridge of the gantry, then vertically downward, and finally horizontally to the axles of the wheels. Such an apparatus is capable of a speed of transportation of about four miles per hour.

A broad-gauge apparatus was constructed for the Maryland Steel Company, Sparrow's Point, near Baltimore. This latter machine runs on a track having a gauge of 14 feet 6 inches. It is capable of lifting 7½ tons at a radius of 40 feet.

A somewhat similar device, except that it is equipped with an entirely different type of crane apparatus, is shown in the illustration. Here it is a question of unloading a rigged sailing vessel and loading railway cars. By examining the photograph, one may see that the booms of the cranes occupy positions between masts. Clamshell grab-buckets are used, one being seen close to the deck. Evidently the booms may be withdrawn to permit movement of the vessel. The size of the apparatus, which is another McMyler device, may be judged by the fact that two railway tracks are straddled by the gantry frame.

WRECKING CRANE. INDUSTRIAL WORKS, BAY CITY, MICH.

Another example of traveling bridge crane is the celebrated Hulett unloader, which was built by the Wellman-Seaver-Morgan Company. The gantry frame here straddles four railway tracks. The deck of the whaleback, with its great openings into the monster hold, is seen alongside. Above one of the openings is the double shovel with its tube above. The man who operates the shovel has his station within. The object of this arrangement is to control the movements of the shovel when engaged in getting the load down in the hold. This is an electrically-operated crane, capable of a lifting movement of the load, a transverse motion of it relative to the tracks, and finally of a longitudinal movement of the entire apparatus along its own track. The Hulett unloader is, perhaps, the greatest ore unloader that has so far been produced. Four of these machines are shown engaged with the big Lake steamship, the *Augustus B. Wolvin*. The shovels at each end are clear of the vessel's hold, but are probably about to descend for their loads. One shovel



TRAVELING CRANE LOADING RAILROAD CARS. MC MYLER MANUFACTURING COMPANY, CLEVELAND, OHIO

is even now in the hold. Apparently, the fourth is just leaving the hold with its load. The scene is at the dock at Conneaut, on Lake Erie.

THE EVOLUTION OF THE PLANING MACHINE—II.

By Thomas R. Shaw

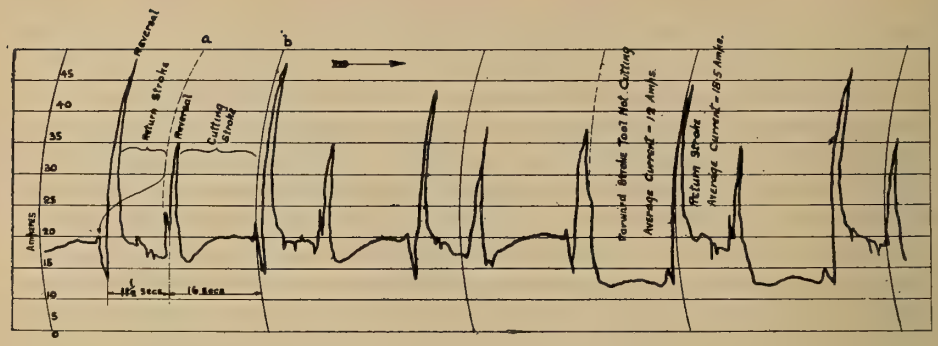
WHEN electric driving came into being planing machines naturally came in for their share of attention, and, owing to the heavy duty demanded, the independent motor for each machine came to be regarded as the best practice. It will be observed that all the electrically-driven machines selected for illustration have their motors carried on the machines, thus making them entirely self-contained. As motors have increased in their efficiency, there is a growing tendency to couple the countershaft direct to the armature shaft without the use of reducing gearing.

Ever since planing machines were driven by electric motors, it was noticed what a great excess of power was required at the moment of reversal. No doubt it was noticed before, only this phenomenon did not present itself in such an objectionable way as when a motor was used. Owing to the great rush of current, there was sparkling and burning up of brushes and commutators. There also are delicate electrical recording instruments that indicate exactly the amount of current being used at any particular point. The reciprocating motion of the table requires the reversal of nearly every part of the mechanism, and at each reversal considerable momentum has to be absorbed and then re-initiated in the contrary direction. The motor for a planing machine should, therefore, be of such a size that it is not only large enough to drive the machine when taking the heaviest cuts the machine will stand, but also able to safely stand fluctuating loads and the overload at the reversals.

In the nineteenth century 20 feet a minute was regarded as a good standard rate of cutting for a planing machine. To-day 40 feet a minute may be considered the standard. If planing machines cut on both strokes, doubling the speed of cut would double the work done in a given time; but if the machine has an idle return stroke, it is necessary to double the speed of the return stroke as well as that of the cutting stroke in order to get a 2 to 1 improvement. A 3 to 1 ratio of quick return was considered good when the cutting stroke was at 20 feet, and this gave a return speed of 60 feet. To make a 2 to 1 improvement, one must not only double the cutting speed, but must preserve the ratio of 3 to 1, which doubles also the idle return speed and brings it up to 120 feet per minute. With a sufficiently powerful drive there is no difficulty in accomplishing this, and it is greatly facilitated when electric motors are employed.

The shifting belt system of driving, in common with most mechanisms, has certain disadvantages, which some people endeavour to make more of than is justified. One is, that for heavy machines, the belts, when made very wide, require considerable force to move them, and being slower in moving across the pulleys, there is time lost in reversing before the table recovers its speed. This difficulty may be overcome by making a double set of driving pulleys and dividing the width of the belts between them.

Perhaps a more serious objection is, that for high speeds of return, there is so much momentum to be



POWER DIAGRAM FROM OLD-STYLE PLANER

absorbed and then re-initiated at each reversal. The idle return stroke has always been a source of annoyance with planers, and we have noted how the early machines cut on both strokes. This has been found not to be generally practicable, and so devices are continually being brought out to enable a very rapid speed for the return stroke. The troublesome momentum which has to be overcome is not in the table, but in the rapidly running pulleys and gears, and the difficulty is not so much the stopping of the running parts at the end of the return stroke as in *starting them at the beginning of the return stroke.*

By its own momentum a table would move through a very short distance. The question then arises, "Where does it get the momentum from?" It gets this momentum entirely from the rapidly running pulleys, and to a small extent from the gearing.

A simple example will explain this. In a planing machine of the ordinary type with a two-belt drive and pulley of different sizes, with light steel rims, the peripheral speeds of the rims are 4,700 feet and 3,510 feet per minute respectively for a table speed of 100 feet per minute.

Weights of 14 pounds in the larger and 10 pounds in the smaller, distributed in the rims of the pulleys, would require expenditures of 1,330 and 530 foot-pounds of energy to accelerate them from a state of rest—a total of 1,860 foot-pounds. Obviously, the energy required to accelerate the entire gear would be represented by a much higher figure.

The power required to accelerate a table, 3 tons in weight, to a speed of 100 feet per minute is 290 foot-pounds, so that there is 6.4 times as much energy in the pulley rims alone as in the table.

This is an example from good practice, and we can easily see, when we consider the formula $\frac{M v^2}{2 g}$, how this ratio would very rapidly increase with any increase in the weight of the pulley rims, particularly in the peripheral speed, as the latter increases as the square of the velocity.

Even taking all this into account, a belt seems to be a most efficient medium in dealing with this problem. It comes on to the pulley gradually (comparatively speaking), slipping a little at first, and slipping less and less under the speed of the pulley equals the speed of the belt. The operation of the belt is interesting, as well as peculiar. As its slip increases and the belt and pulley get warm, the hug of the belt is closer. In short, a belt has all the desirable features for starting and stopping a load without shock, and it is, and will continue to be, incorporated in many of the best designs.

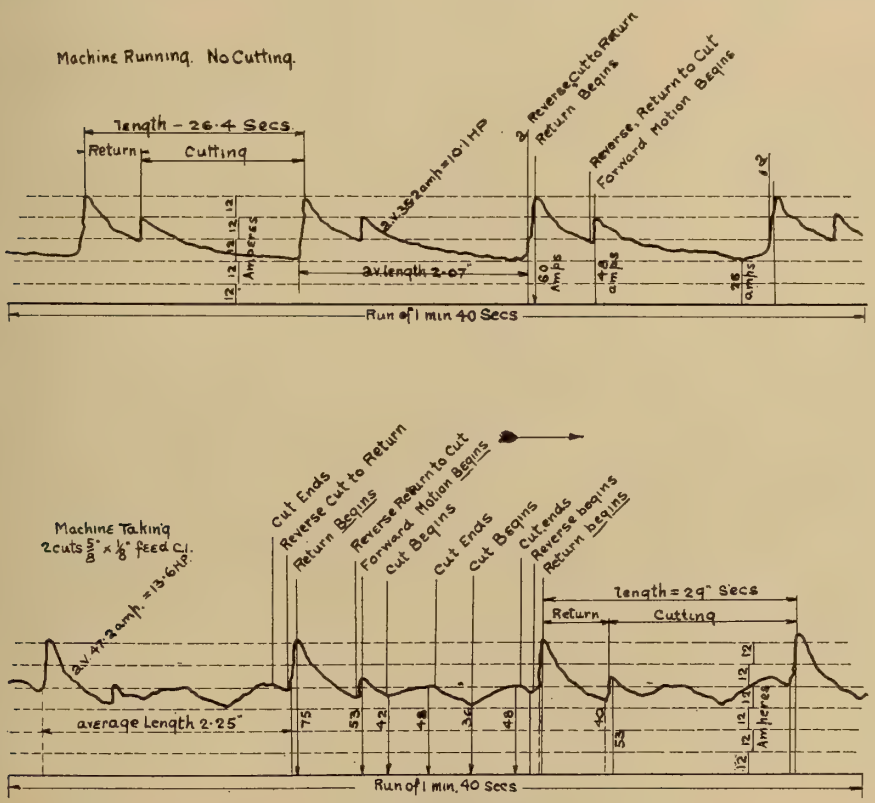
To reduce as far as possible the fly-wheel effect of the machine

pulleys, the rims should be made of steel, and of the lightest possible construction compatible with safety.

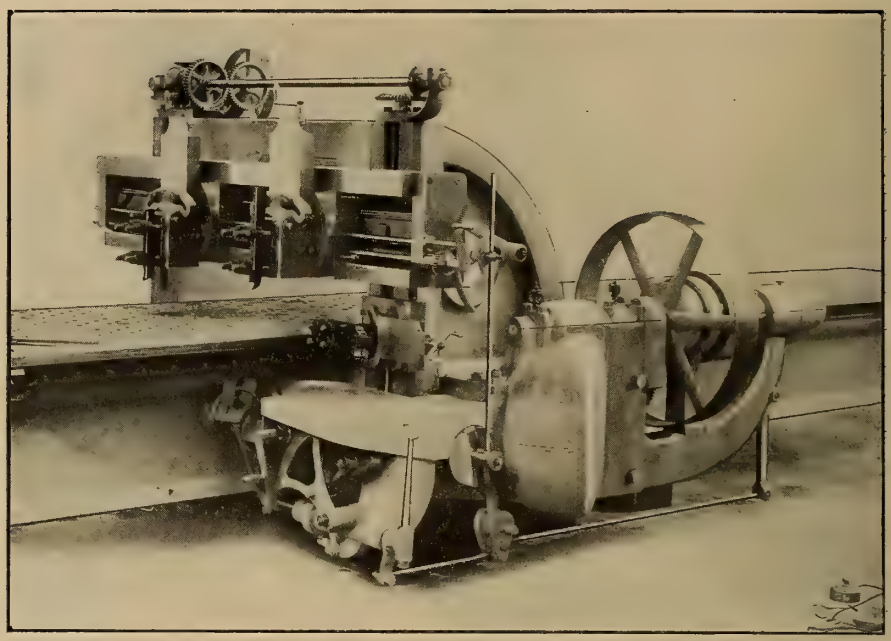
It must be borne in mind that the table and all its gearing have to be *started from rest* at each stroke. For this reason it is an advantage to have the return pulley large in diameter, so as to have as long a leverage as possible to help in starting the parts on the quick return, and some makers use a return pulley as large in diameter as the cutting pulley. But with this arrangement there is the objection that there is an increase in the momentum which has to be overcome, owing to the increased rim speed, and also that the bolt speed becomes too high for practical use. The return belt, owing to its higher speed, always exerts a greater pulling force than the cutting belt; therefore, it seems advisable to have the return pulley smaller than the cutting, and thus strike a happy medium between the conflicting factors—time of reversal and waste of energy.

It has also been found that fly-wheels on the countershafts give beneficial results. These are running continually in one direction, and the action of the fly-wheels is to steady the running and assist the action of the belts at the point of reversal. It is now customary to make the two driving pulleys on the countershaft with heavy rims for this purpose. Primarily fly-wheels were used with electric motors to preserve these from excessive shock, but their use has become extended to ordinary belt-driven machines.

With electrically-driven planers, the use of the recording ammeter enables a graphical showing to be made of the power consumed during any



POWER DIAGRAM FROM MODERN PLANER



SELLERS 5-FOOT PLANER WITH OPEN AND CROSSED BELTS AND CLUTCHES

period of time, or cycle of operations, of the machine being tested. The diagrams in Figs. 1 and 2 show clearly the great excess of power required at the point of reversal. Fig. 1 is a diagram from an old-fashioned planer with the old style of gearing, and running at a very low rate of speed, the average speeds being 22½ feet per minute cutting and 31½ feet returning. The diagram is of interest, as it shows the difference between cutting and running idle. The very irregular line on the return stroke is, no doubt, due to the effect of the idle running gears with cast teeth.

The two diagrams in Fig. 2 are from a test of a modern type planer, the top one being taken when the machine was running idle and the lower one with the machine taking two cuts in medium hard cast iron, each ⅝ inch deep, with a feed of ⅛ inch. The machine was driven by a 15 horse-power compound wound motor running at 400 revolutions per minute. An extension of the armature shaft carried the pulleys direct, and also a heavy fly-wheel, the utility of which will be seen upon examination of the diagrams.

The travel of the table was about 8 feet, and two surfaces were cut, about 26½ inches long each, with a space between, so that the cut was continuous. Summarizing the results, we have:

Power required on forward stroke—no cut, 10.3 horse-power; power required on return stroke, including reverse, 16.9 horse-power; power required at time of heaviest cut, 14.4 horse-power; power required at moment of reverse from cut to return, 22.4 horse-power; power required at moment of reverse from return to cut, 16.3 horse-power; power required as average throughout entire cycle, 13.6 horse-power; time required for one cycle, 29 seconds; approximate cutting speed, 25 feet per minute; approximate return speed, 75 feet per minute.

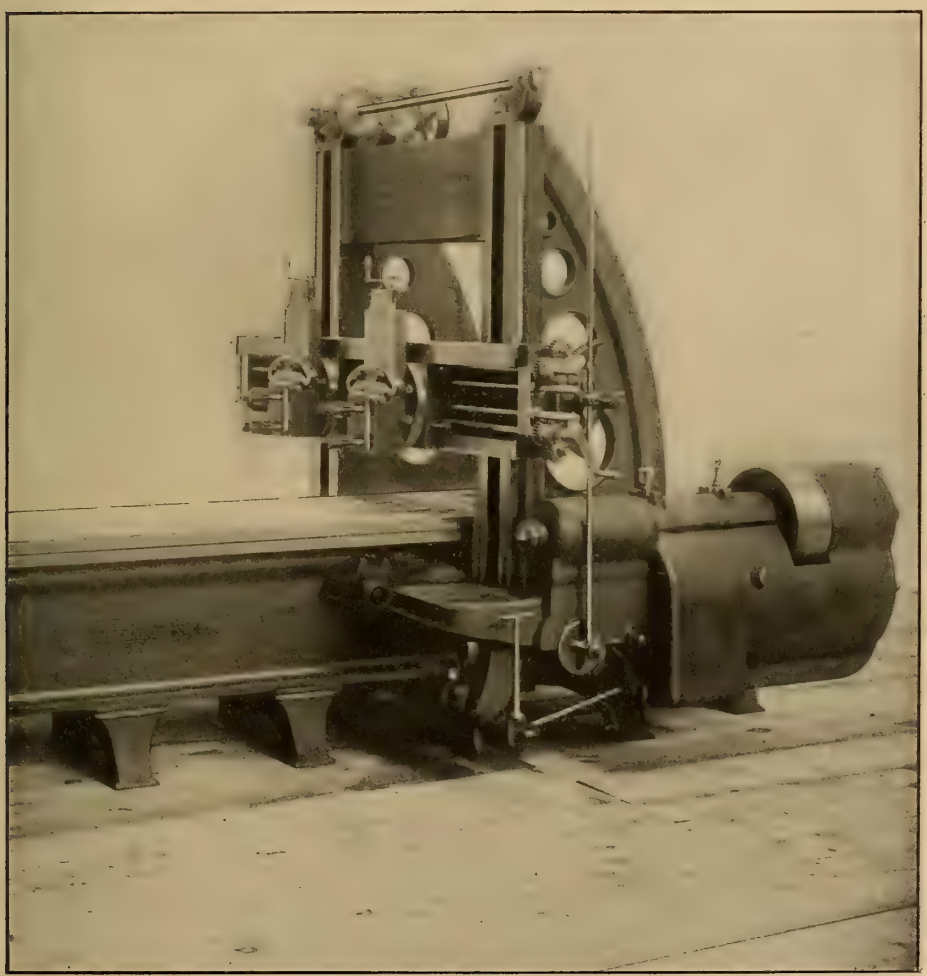
The power included the whole drive, including motor and countershaft.

From the above diagrams it will

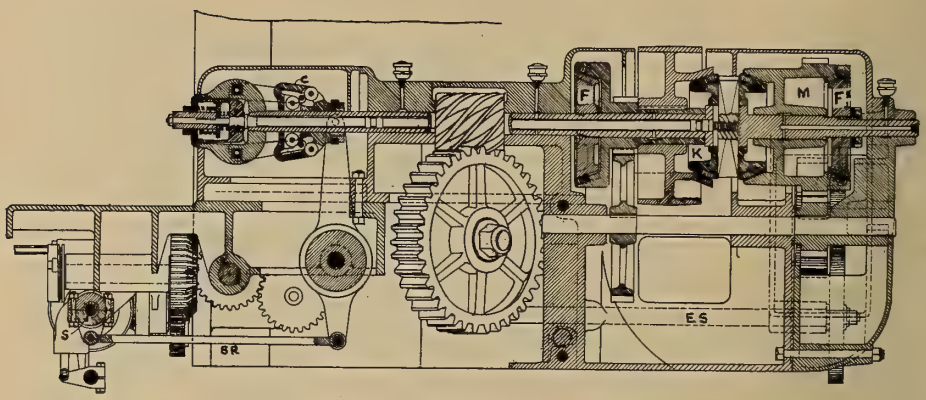
be seen that the ratio of return to cut is 2.4 to 1, while the table movement, as recorded by a cut-meter, was in the ratio of 3 to 1. The difference between these two ratios may be taken to be time loss at reversals.

It will be seen that the power required to reverse the direction of the table movement from cut to return was the highest, being 22.4 horsepower, an increase of 55 per cent. over the power necessary at maximum cut. This maximum power is much less than might be expected from a machine of this size, and the very favourable result shown is undoubtedly very largely due to the fly-wheel on the countershaft. A fly-wheel requires some expenditure of power to keep it in motion; but as this is a relatively small amount, it is more than compensated for by the advantages obtained by its use. The effect of its action will be seen on reference to the diagram. The depth of the cut was quite uniform throughout its length, yet there is no sudden rise in the power line at the point where the cut begins, the rise being gradual up to the point of maximum power.

We now come to the various de-



SELLERS SINGLE-BELT-DRIVE PLANER WITH MECHANICALLY-OPERATED CLUTCHES. PATENTED 1893



ARRANGEMENT OF GEARING ON SELLERS "1893" PLANER

The gearing runs continually in one direction; only the clutches reverse

vices adopted for obtaining very high speeds. The advent of the high-speed tool steel in 1900 caused a demand for high-speed machines, but long before this efforts had been made to obtain a high rate of return speed. The problem is a fascinating one, and has been attacked a number of times and by a number of people. There are some still working at it. As already mentioned, shifting belts have their limitations, and it has long been recognized that it would be advisable to get along without them. This led to the clutch-driven planers. All kinds of clutches have been designed to do the work, a few good, but most of them bad, worse, or impossible. It was readily recognized that positive clutches would not do, so the inventors and designers settled down to the friction clutch. The manner of throwing in the clutch, or, rather, the method for getting pressure behind the clutch, is of importance, although it makes very little difference whether the clutch is thrown in by air, electricity, or a lever; its limitations, and the troubles it causes, lie in something else. The whole story is this: a friction clutch slips, or else it does not slip. When it slips, it does not work; and when it does not slip, then it is a positive clutch, and, therefore, no good for a planer. The ideal friction clutch for a planer should slip enough to pick up the load gradually, and yet quickly, and should not slip at all when taking the heaviest cuts the machine has to take. This sounds simple, but to make such a clutch is a different thing, and many have been foredoomed to failure, through misconception of the vital principles in a planer drive. The more one looks back and considers the things that have been done in practice, and the more the old designs are studied, the more one is impressed with the importance in a designer to know what is settled by experience and where to stop trying to substitute new devices or impracticable ideas.

We must now retrace our steps and go back to the year 1887. The firm of William Sellers & Co. have, perhaps, had the most extensive experience in planing machine construction, and they were the first to introduce a very high speed of return. They have carried out experiments and passed through a complete process of evolution with their own machines, some of which we will now consider.

In 1887 Messrs. Wm. Sellers & Co. were granted a patent for a planer having two belts running in opposite directions but which did not shift. It was sought to increase both the driving power and the speed of the return, and naturally higher belt speeds were necessary. In order to

reduce the fly-wheel action of the high-speed parts subject to reversal of direction, a friction clutch was substituted for the shifting belts, in which the high-speed reversing member was reduced to the smallest possible dimensions, and the clutch operating mechanism was so actuated as to apply a brake gradually, to bring the table to rest before the reversing power was fully applied. This device is described below. It enabled them to obtain greater return speeds than had been obtained before—viz., 144 feet per minute on planers up to 5 feet wide.

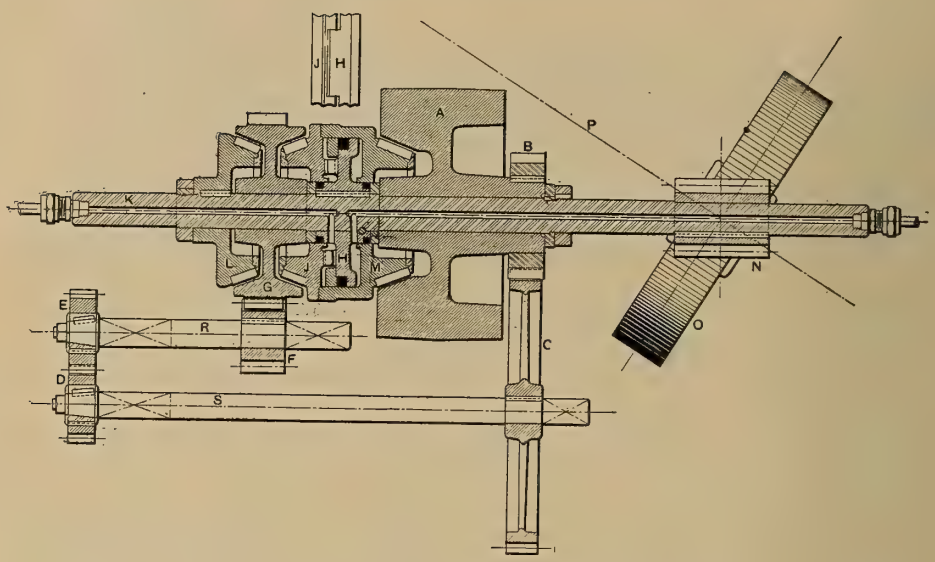
Among the improvements introduced at this time was the use of the spiral gear and spur wheel, in place of the bevel wheel and pinion formerly employed. This permits a higher ratio of gearing, as the number of teeth in the spiral pinion may be made much smaller than the number of teeth in the bevel pinion. More important than this, however, is the fact that the action is continuous, like that of a screw, and there is absolutely no shock as the teeth enter and leave. Thus the motion of the pulleys is communicated to the table without vibration, and the work produced is entirely free from chatter marks.

Another feature introduced at this time was in the table guides. Recognizing the difficulty of fitting two V-guides, and that flat guides require the introduction of adjusting strips, they made the table with one flat and one V-guide, making the angle very large to reduce the friction and making the projected areas equal. In addition to the flat V-bearing, two nearly vertical sides were provided and finished, so that there was a slight clearance between the table and the bed on these nearly vertical faces. The slightest motion of the table sideways would, therefore, bring two of these nearly vertical faces into engagement and a further side movement of the table be prevented. This, of course, would only occur with very heavy side cuts. On light cuts the table would run on the flat portion of the V with corresponding reduced friction.

Fig. 3 shows one of these planers as arranged with this drive. The driving belt ran on the large pulley and the return belt on the small one behind it. The machine shown in the illustration was of 60 inches width, 18 inches high, and designed especially for planing locomotive side frames.

The next radical step made by Messrs. Wm. Sellers & Co. was to employ one driving belt only, and such an arrangement of driving was patented by them in 1893. A machine with this drive is illustrated by Fig. 4, and Fig. 5 shows the arrangement of the clutches and controlling mechanism. The belt ran at a constant speed for returning, and drove the forward motion clutch through a suitable train of reducing gears. It should be noted that there is a pair of clutches for each motion, to ensure a good drive. The clutches marked F are fixed to the driving shaft; the other clutches are all free to slide endwise, K being a double clutch and secured to the shaft by a cotter. For instance, if clutch K is moved to the right into the wheel M, this latter is forced against the fixed clutch F^1, and M drives the shaft through K and F^1. It should be particularly noticed that the principal high-speed rotating parts revolve continuously in the same direction, and that there is no reversal of high-speed pulleys or parts with high peripheral speeds. The fly-wheel action of the parts whose motion is reversed, owing to their relatively small size, is then reduced to the minimum, and loss of power incidental to their reversal is avoided. The gearing runs continually in one direction, and only the clutches and two last motion shafts reverse. This approaches very nearly to an ideal driving gear.

The clutches are conical and lined with blocks of hard wood. The sliding clutch is operated by an internal rod actuated by bell-crank levers of



LOCOMOTIVE COALING CRANE, HANDLING 2-CUBIC YARD BUCKET. INDUSTRIAL WORKS, BY CITY, MICH.

the familiar type found on the spindles of turret lathes. When the table comes to the end of its stroke, the brake action referred to above is applied gradually through the clutches to bring the motions to rest before the reversing power is fully applied. This acts as follows:

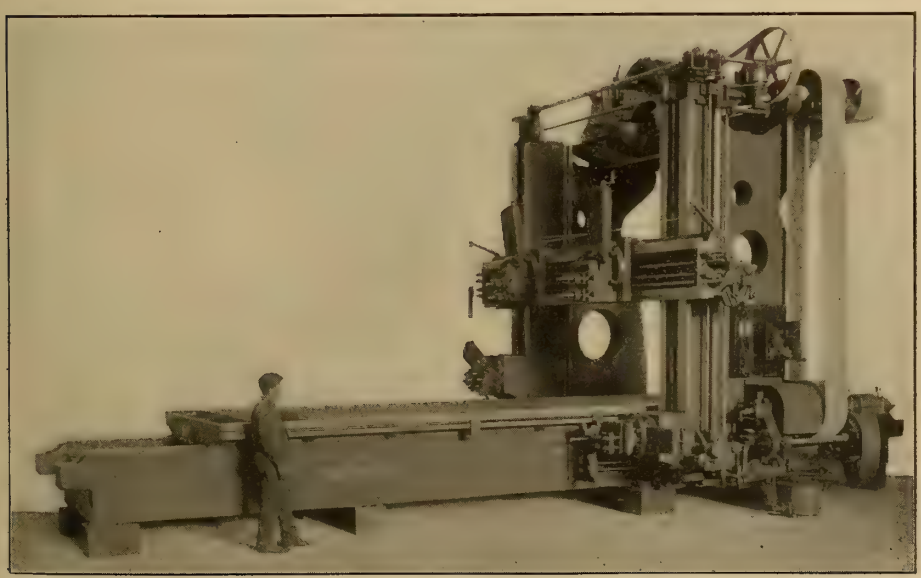
When the table dog strikes the reversing lever, the shifting rod (*S R* in figure) is moved, and with it the lever and sliding cam *C*, carrying the ends of the bell-crank levers. This, acting on the internal rod, withdraws the clutches from the driving gears and presses them against the pulley with a pressure resulting from the compression of a spring so as to act as a brake and retard the motion without reversing it until the forward motion of the table has ceased. An independent friction clutch is used to grip the oscillating shafts and prevent any falling away of the rod *S R* after it has been once moved. The action of the dog also withdraws an abutment, and so releases an escapement which permits another mechanism to make a complete half-turn. This acts on a cam and transmits positively a further movement of the rod *S R* and sliding cam *C*, and so presses home the clutches for the return motion. The escapement train is positively driven continuously in one direction from a shaft *E S* driven from the driving gearing. The action of finally pressing home the clutch is thus positively operated. The feed motion is also operated by the escapement train.

Sellers' next departure was to substitute compressed air for the mechanical lever system employed in the last-mentioned construction for operating the clutches, and to interpose in the reducing train a pair of change wheels by which the ratio may be altered to produce different cutting speeds with a constant speed of return. This arrangement is shown diagrammatically in Fig. 6. The shaft *P* carries the spiral pinion driving the table, and at the outer end is a spur wheel *O*. This is driven by the spiral pinion *N* on the pulley shaft. The driving pulley *A* runs loose on the pulley shaft *K*. It runs continuously and in the same direction while the planer is in operation. On the hub of the pulley *A* is a pinion *B* driven through a reducing train of wheels *C, D, E* and *F* to a loose wheel *G* on the pulley shaft. It

is evident that the wheel *G* will run in the opposite direction to the pulley *A*, and at a reduced speed, depending upon the ratio of the wheels in the train. The pulley *A* is turned on one side to form the female half of a conical friction clutch. The wheel *G* is turned on both sides in a similar manner. *J* and *M* are two conical male elements bolted together and forming an air-tight cylinder free to move back and forth on the disc *H*, which is keyed and pinned to the shaft *K* and forms a piston in the cylinder. In order to compel the shaft to rotate with the friction clutch, the head of the cylinder *J* has notches for the teeth on the surface of the piston *H*. These form a claw clutch, and permit end movement, while they compel the parts to rotate together. Air admitted to one end of the cylinder through the centre of the shaft *K*, for example between the parts *H* and *M*, will cause the cylinder to move in the direction of the pulley *A*, to press the friction cone against the pulley, and cause the clutch to rotate with the pulley. This movement will be transmitted through the piston *H* by the clutch teeth and cause the shaft to rotate in the same direction, which produces a return movement of the table. Admitting air to the opposite end of the shaft will cause *J* to engage with the wheel *G* and force the latter against the stationary clutch *L*, which is keyed to the shaft. The wheel *G* will thus drive the shaft through both the clutches. *D* and *E* are the change wheels.

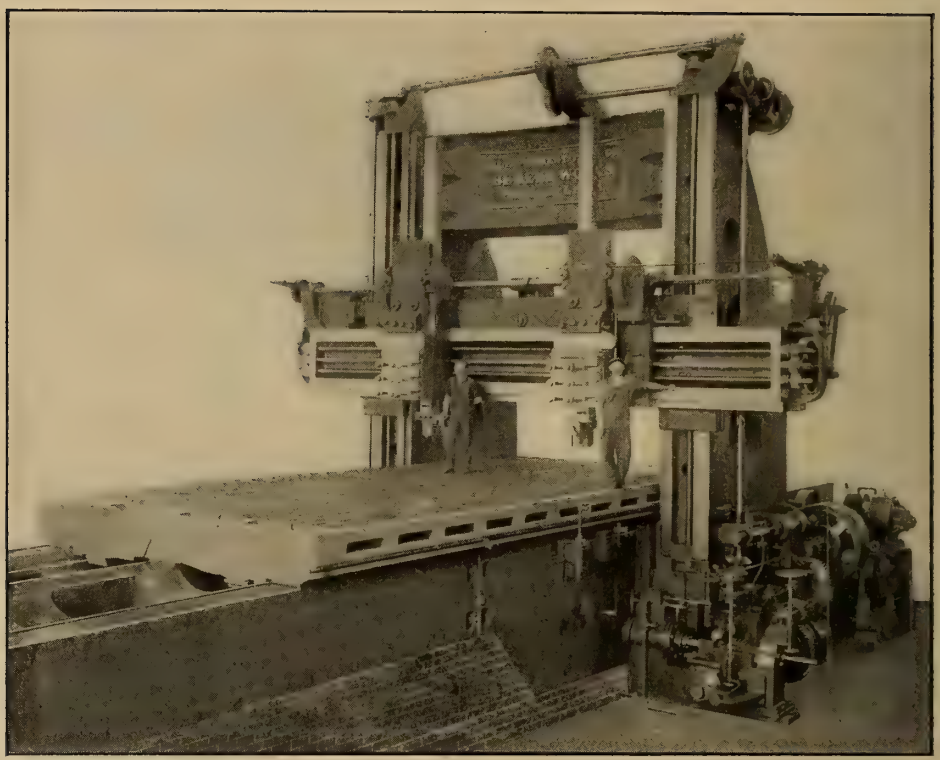
The compressed air is obtained either from the shop installation or from a compressor attached to the machine.

In operation, the table stops move a valve, which admits compressed air alternately to opposite ends of the cylinder, and by regulating the velocity of the admission the speed of reverse can be nicely gauged. The table is brought to rest promptly, and started up in the opposite direction without shock. Messrs. Wm. Sellers & Co. have made a complete range of these machines, from 3 feet to 14 feet wide. Fig. 7 illustrates their 8-foot machine, and is a typical example of the most modern planing machine construction, embracing features in



SELLERS 8-FOOT SPIRAL-GEARED PNEUMATIC CLUTCH PLANER

Motor 50 horse-power, driving belt 11 inches wide, 2,500 feet per minute



BELTLESS PLANER, DRIVEN BY ELECTRIC MOTORS AND PNEUMATIC CLUTCHES. NILES-BEMENT-POND COMPANY, NEW YORK

its design which enable it to meet the most exacting conditions of shop practice. A point of considerable interest is that they do not, with these their latest machines, go in for fancy speeds of returning, believing, in common with some of the best judges of planers, that excessively high return speeds are not as economical as at first supposed, and that "the game is not worth the candle." The table gives the return speeds of their various sizes.

Size of Machine	feet per minute
3 and 4 feet wide	100
6 feet wide	93
7 feet and upwards	80

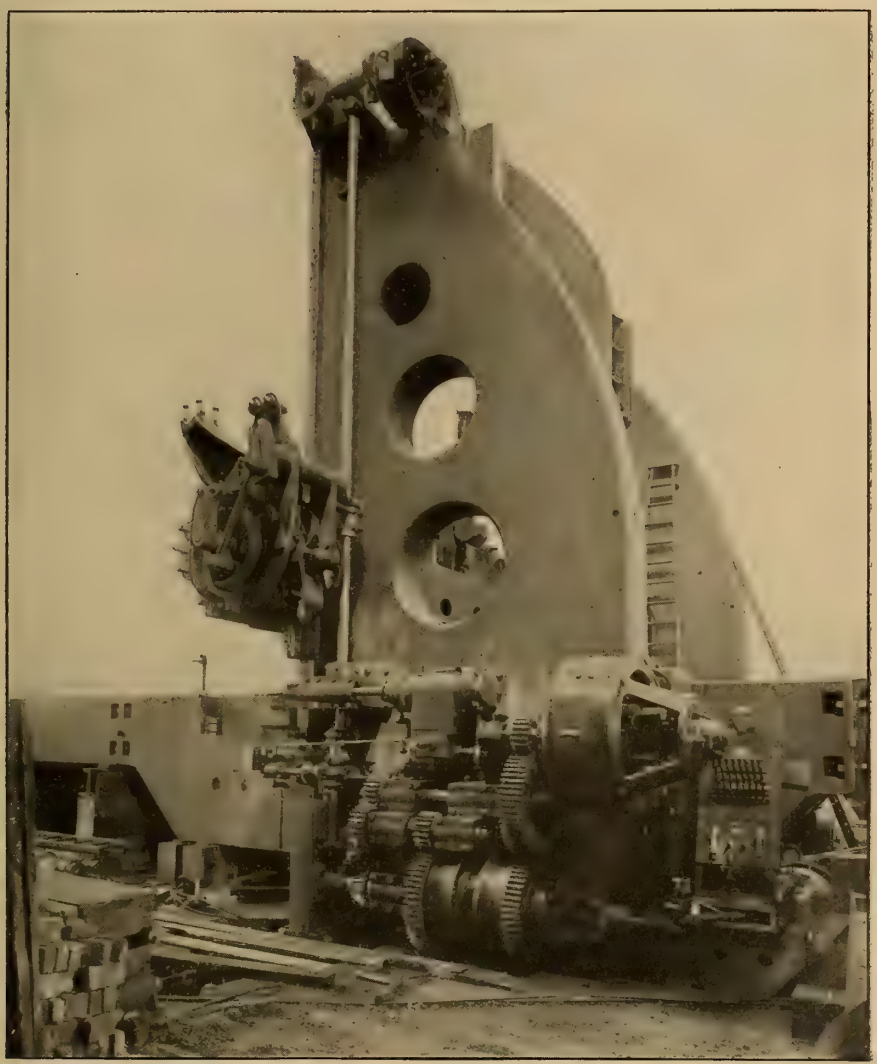
The table is supported by the patent slide ways, as already mentioned, and the ways are kept in a continuous state of lubrication by means of a force pump and circulating system, by which the oil is returned to the tank after being filtered.

Another important feature of this machine is the construction of the cross-slide. This is extended between the uprights, and can be bolted not only to the outside flanges in the usual manner, but also to the inside surfaces. This not only ties the uprights together in a superior manner to resist the strain of side cutting, but it increases the torsional strength of the cross-slide to a very marked degree. The feed motion is driven by a separate pulley overhead, from which also the elevating motion is obtained. The feed is operated through a clutch held out of engagement during the travel of the table, but ready to engage when released by the actions of the dogs at each reversal of the table, so that the driven parts make a half turn before the clutch is again released. This motion is communicated, through a vertical shaft, to the feed discs, of which

there are two on the end of the cross-slide, and act independently for each tool box.

The belt on this machine is 11 inches wide, and runs at a speed of 2,500 feet per minute, at which speed it is capable of transmitting over 50 horse-power. This gives a return speed of 80 feet per minute. The motor as shown is of 50 horse-power. The table rack, of 2¾ inches *P* and 10 inches face, is driven by a spiral pinion having five threads. The weight of the machine is about 60 tons.

In America the pneumatic clutch is at present considered the best for planer drives, and is used very extensively. The Niles-Bement-Pond Company recently completed a gigantic planer—the largest in the world—which was equipped with pneumatic clutches for the main drive, and also for some auxiliary drives. This huge machine, shown in Figs. 8 and 9, weighs over 400 tons,



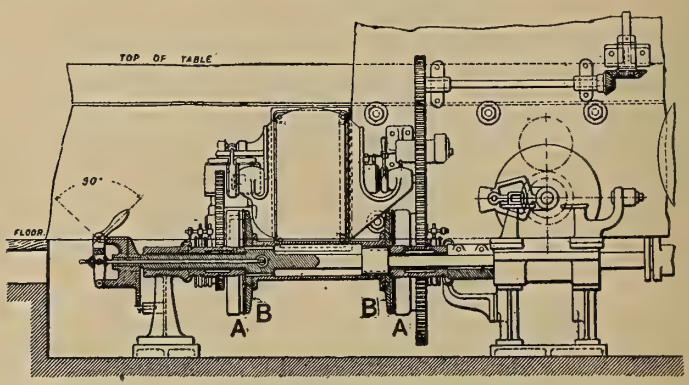
100-HORSE-POWER PLANER OF NILES-BEMENT-POND COMPANY, NEW YORK

and requires motors with a total of 207½ horse-power. The main drive for the table is of 100 horse-power. The motor has a slight variation in speed, by means of which the table speed may be easily changed to a small degree and further changes be obtained by gearing. Power is transmitted by gearing from the motor to reversing clutches of the multiple disc or Weston type, operated by compressed air supplied by a compressor which is a part of the machine, and driven by an independent motor. Shifting belts would be impracticable for such high power; the most satisfactory method is the use of pneumatic clutches.

Amongst various clutches which have been tried is the magnetic clutch, Fig. 10, which at one time promised to be a successful solution of the planer drive, but has failed to come up to the high expectations it raised, possibly because the average tool builders and users are not sufficiently well acquainted with the electrical conditions introduced. A magnetic clutch consists of a pair of iron-clad electro-magnets and a disc which is attracted now by the one, and then by the other, according to which magnet receives the current. A simple reversing switch operated by the table dogs controls the current. The magnetic clutches *A* are rotated in opposite directions, and at speeds corresponding with the forward and return strokes of the table. They alternately attract and grip the discs *B*, which are connected by a sleeve and slide endwise on the driving shaft of the machine to which they are keyed. Reference to the drawing will show that these discs are so made that the fly-wheel effect is reduced to a minimum.

To reduce the fly-wheel effect is the object sought in all clutch drives, and the difficulties with them would be overcome if it were possible to devise a clutch of small bulk and weight, great staying power, and requiring only a small gear reduction.

It is with interest, therefore, that we find a planing machine drive invented by Kellow in 1902 which does not involve the use of shifting belts, nor the reversal of any part of the gearing other than the rack pinion and the shaft on which it is mounted. These parts being the slowest of the moving mechanism, the objection to their reversal is practically negligible, and if the figures given on page 234 are studied, the advantages will be manifest, because the power required at reversal is only slightly above that required to accelerate the table. Applied to a planing machine, the table of which is 12 feet by 5 feet, this drive gives a speed of 40 feet per minute cutting and 200 feet per minute return. The writer has not seen this machine at work, but has been assured on good authority that at

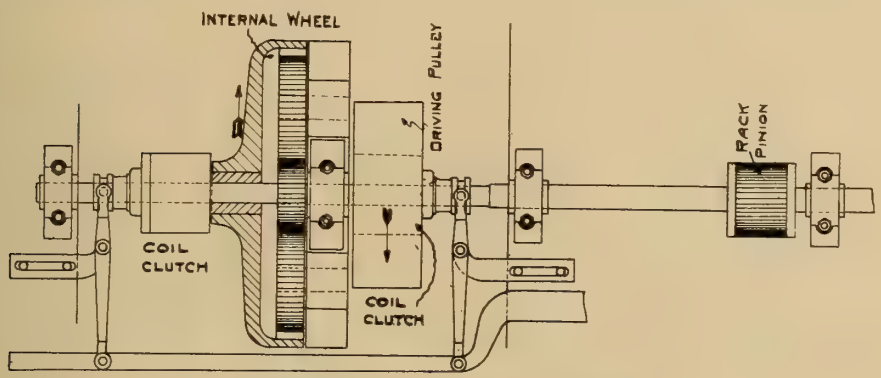


ARRANGEMENT OF MAGNETIC CLUTCH DRIVING GEAR

these, and even higher speeds, the working is perfect.

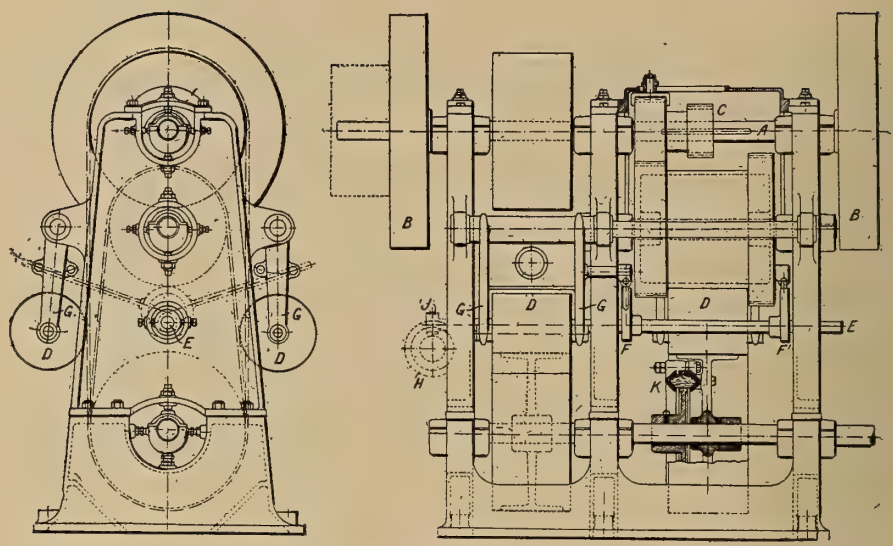
A diagram of the drive is given in Fig. 11. There is one driving pulley running constantly in one direction, and to this the rack pinion shaft is clutched directly for the return stroke. For the cutting stroke, a pinion keyed to the pulley drives an external wheel through the medium of two intermediates running on studs in a fixed bearing. This internal wheel is, in turn, clutched to the rack pinion shaft. This is the whole of the gearing, and it will be obvious that the success of this drive depends entirely on the perfect working of the clutches.

These are coil clutches, and a word about them will not be out of place here. The principle of the coil clutch is fundamentally the same as that of the ordinary capstan. If a sufficient number of turns of rope is taken round a capstan the friction becomes great enough for the rope to grip. In the coil clutch the place of the rope is taken by a coil of special mild steel, the interior surface of which is turned smooth and highly polished. This is fitted upon a chilled cast-iron sleeve, the surface of which is also ground to a polish. When the clutch is not transmitting power the difference of the exterior diameter of the sleeve and of the interior diameter of the coil is only such that the former can revolve in the latter with practically no friction, lubricant being freely applied between the two surfaces. The clutch should preferably run in oil. One end of the coil is always fixed, being connected to the driving plate, while the other is free to move. If, now, by a special device, the coil is wound up slightly further, its interior diameter tends to decrease. As soon as this happens the coil begins to grip on the sleeve, and a little further winding up of the coil makes this gripping action so strong that, for the time being, coil and drum become practically one, and power may be transmitted through them. These clutches, when properly constructed to meet their requirements, are not injured by shocks, as may be gathered from the fact that clutches are at the present time reversing rolling mills three times a minute. The coils have just been renewed after fourteen years' service.



KELLOW'S PATENT CLUTCH DRIVING SYSTEM

We will now turn back to the belt drives. Owing to continuous trouble with magnetic clutches on some large planers at the works of the British Westinghouse Company, a belt drive was invented by Mr. W. C. Mitchell, It was first applied to a 14-foot-wide machine, and proved so much superior to the magnetic clutches, and was so successful in operation, that it was applied to a number of other planers ranging from 5 to 10 feet in size, displacing both magnetic clutches



THE MITCHELL BELT DRIVING GEAR

and shifting-belt drives, and permitting return speeds of 150 feet per minute.

The Mitchell drive is a belt drive, but differs from the shifting-belt drive in that any width of belt may be used and any amount of power delivered to the machine. It is made as a complete piece of mechanism in itself, as shown in Fig. 12, and may be applied to either new or old planers, or to other machines requiring a reversing mechanism.

The drive is very simple, and is, briefly, a method of running two loosely-hung belts in opposite directions. Each belt is run at whatever speed is desired, and is alternately tightened by means of a jockey pulley. The principles followed in evolving this device were: The reversing shaft, with its pulleys, must be kept as tight as possible to reduce inertia effects on reversal; the driving shafts, pulleys, and all other parts revolving in the same direction must be made heavy to take advantage of a great fly-wheel effect. The slipping of the belts on the pulleys must be reduced to the smallest possible amount, and the machine must be reversed without shock and in the shortest time possible.

The jockey pulleys operate on the slack side of the belts and cause such a large arc of contact to be embraced by the belts on the pulleys that there is no appreciable slip between the belt and the pulley, and the machine is reversed instantly. A little slip is necessary, however, to enable a planer table to be reversed without shock, and this is provided for by means of an adjustable slipping clutch.

In Fig. 12 A is the first motion shaft, running at a speed of 600 revolutions per minute, and carrying two heavy fly-wheels *B B*, the energy stored up in which is given out at the moment of reversal and tends to smooth out the peaks generally seen on power diagrams. The drive is arranged for a constant return speed and two rates of cutting speed obtained by means of sliding wheels at *C*. The belts run in a vertical direction, and the jockey pulleys *D* are pulled in and out by means of a rocking shaft *E*. At *F F* are ball-bearing eccentrics coupled to the swinging jockey pulley frames *G* by adjustable connecting-rods. The rocking shaft *E* is operated by the dogs on the planer table. Several methods of operating this shaft by the dogs are used according to conditions. In

smaller sizes the action is direct. In the larger sizes, however, the shaft *E* is operated by power, using preferably compressed air. The dotted lines at *H* show the location of the air cylinder, a piston which is provided with rack teeth, and these mesh with a pinion *J* on the end of shaft *E*.

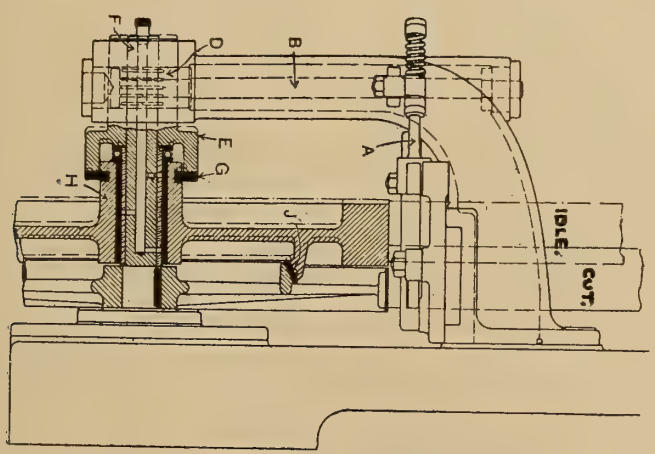
The slipping clutch is shown at *K* connected to the driving pulley for the cut, as it is on this pulley that the work comes of pulling up the quickest moving parts at the end of the return stroke. This form of clutch, consisting of wood blocks of a double V-section between two plates held together by spiral springs, has been found very satisfactory. This gear is made by the Mitchell's Auto Reversing Gear Syndicate, London.

To enable a very quick retardation and acceleration of the parts at the moment of reversal, the use of a fly-wheel combined with a friction clutch, by means of which the stored-up energy in the fly-wheel is given out, was invented in 1903 by Herr Kindermann, chief engineer of the Saxon Engine Works. This fly-wheel and clutch is the principal feature in the "Bateman" high-speed planer. This machine is a shifting-belt machine, and the driving belts run at each side of the machine. The belt is wider than the face of the fast pulley, and a portion is always in contact with the loose pulley, which is in the form of a fly-wheel, and is thus kept continually running in one direction.

The arrangement is shown in Fig. 13. The fly-wheel carries a conical clutch the mating part of which is carried by the fast pulley. The fly-wheel pulley is free to move sideways along its shaft, and the motion of the belt-shifting gear is transmitted to it and moves it so that the friction clutch *J* is brought either into or out of action. This motion is so timed as to take place when the belt is thrown on or off the fast pulley, and, together with the overlapping of the belt from the fast onto the fly-wheel pulley, enables the conserved energy of the fly-wheel to be transmitted into the fast pulley at the moment when a large amount of power is most required.

The assistance of the fly-wheel to the driving belt at this moment reduces considerably the time of acceleration of the table, making the action remarkably prompt. Return speeds are used as high as 210 feet per minute on 2-foot machines, varying to 100 feet on 6-foot machines.

The Chandler Planer Company, of Ayer, Mass., U. S. A., are firm believers in the efficiency of a high-speed shifting belt, and, by means of



BATEMAN AUXILIARY FLY-WHEEL LOOSE PULLEY

a system of three belts, obtain on their machines a very high rate of return, viz., 200 feet per minute on a 2-foot machine, and yet the table reverses smoothly and without shock.

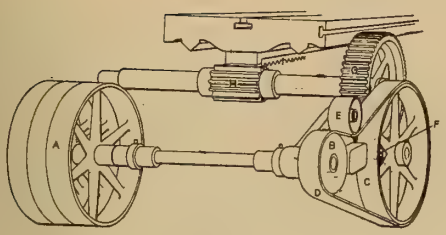
Of the three belts, one is used for driving when cutting, one for reversing and one for running the table back at high speed. As the table approaches the end of the cutting stroke the dog throws off the "cutting" belt and throws on a slow-speed return or reversing belt, running at a speed that will most effectually reverse the cutting movement of the table. The two belts are shifted practically as they are in planers of other makes.

As soon as the table starts back on its return stroke, however, the tappet is again acted on by the dog, throwing off the reversing belt and throwing on the high-speed return belt, thereby accelerating the table speed. This belt remains in action until near the end of the return stroke, when the belts act in the reverse order. That is to say, the belts are again shifted so that the slow-speed return or reversing belt comes into operation and acts as a brake, doing its work easily and smoothly, to bring the speed down again before the cutting belt again comes into operation.

The Chandler planer also has another important feature. It is provided with a variable-speed drive by means of a combination of clutches and gears located in the frame of the machine, and when a slow speed is required it is obtained by double gearing in the same way as in the lathe. Thus a high and constant rate of belt speed is maintained. This feature will be appreciated when it is remembered that where the slow speed is obtained from a variable-speed countershaft the belt power is reduced on just the kind of work that requires an increased power in the belt.

It is always granted that a greater production can be effected by increasing the cutting speed in preference to the return speed; but it is well known that, though a tool will stand a certain speed when cutting, it will not stand this speed when entering the work. A tool stands shock very poorly, and for this reason cutting speeds of planers are frequently kept down, though all other conditions may be favourable for high speed. On this account an American firm, the Powell Planer Company, have recently introduced an innovation which is the opposite to the Chandler machine, as instead of accelerating the return, they accelerate the cut, and this appears to be a step in the right direction. With their arrangement of gearing, they allow the machine to reverse and then start cutting at a normal speed. As soon as the tool has fairly entered the work the cutting belt is thrown on to another pulley, and this driving through gearing, increases the speed of the cut to two or three times the speed at commencing.

The Whitcomb "second-belt drive" is another departure from general practice, and believing that a belt would run smoother than gearing, this firm have developed a line of planers in which the first pair of quick-running gears is dispensed with and a wide belt substituted. The idea is that the absence of the quick-running gears prevents vibration, and, therefore, conduces to smooth work being produced from the machine. The gearing is also running quieter. This second belt is so proportioned as to be capable of transmitting easily all of the power delivered by the driving belts, and is, therefore, practically positive. It is automatically kept at proper tension by a weighted idler pulley. The diagram, Fig. 14, shows the principal features. *A* indicates the usual set of driving pulleys driven by a pair of narrow shifting belts in the ordinary manner. *D* is the "second" belt running upon driving pulley *B* and driven pulley *C*. *E* is the idler pulley which follows up the belt as it stretches and keeps it at proper tension. *F* is a pinion



WHITCOMB SECOND-BELT DRIVE

attached to pulley *C*, and *G* a driven gear mounted upon the rack pinion shaft.

There have been various other devices brought out to relieve the planer of shock. One machine, the Bateman, has the table rack to slide under the table and butt at the ends against strong springs. The writer is of the opinion, however, that the rack should be rigidly secured to the table, and that a much better arrangement is that of Smith & Coventry, in which one of the driving wheels is loose on its shaft and has its hub provided with a clutch tooth arranged like a cam. A similar clutch is mounted on the same shaft and made to slide over a key. A strong helical spring behind this clutch holds the two cam surfaces in contact. When the wheel begins to turn it has a tendency to take the cam and shaft with it. It thus starts the table, but at only a part of its ultimate speed, as the clutch slides back at the same time, and when the table is up to speed the spring presses the clutch fully in again. This arrangement has been applied on machines up to 8 feet wide and having a 40 horsepower drive. A spring cushioning arrangement has also been patented for use with a spiral pinion drive by Messrs. Loudon Bros., Johnstone. The spiral pinion floats between two springs, one of which compresses until the table has got fully started on the return stroke.

A spring buffer is used in the latest high-speed machine, and with this Messrs. J. Buckton & Co., Ltd., of Leeds, claim to have successfully solved the problem of driving planing machines at a very high speed without the consumption of excessive power.

The principle underlying the design is that of balancing the forces by recoil springs. At reversal the springs absorb the momentum of the moving parts and return it during the period of acceleration, thus constituting a complete regenerative system. These springs produce beneficial results other than the large saving of power that they effect. Much time is saved by the promptitude with which the machine reverses and attains its full speed. The reversal is extremely accurate, and although the machine may be cutting at 60 feet and returning at 180 feet, not more than ⅛ inch clearance is required between the tool and any projection above the surface being planed. This accuracy is attained without having regard to modification either of stroke or cut.

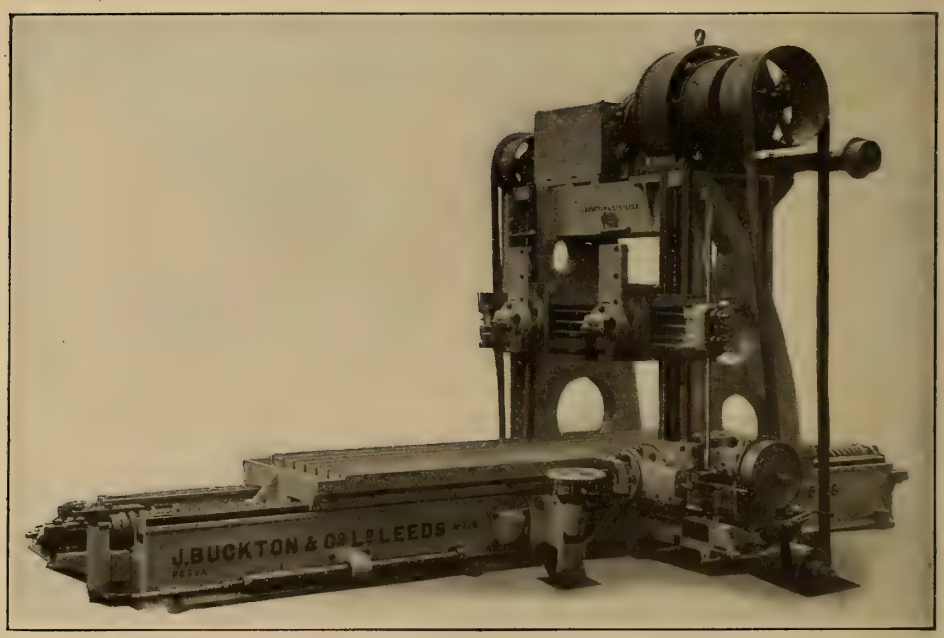
The two springs abut against one of the cross bars of the bed, or gantry; screws pass through these springs and lie along the whole length of the bed. Heavy bronze nuts are adjustable on these screws, and knockers attached in fixed positions to the under side of the moving table impinge on these nuts. Any length and position of stroke is obtained by altering the position of the nuts upon the screws by turning the latter. The length of stroke is adjustable down to 12 inches, and may be adjusted while the machine is running. Such adjustments do not disturb the synchronism of the belt-striking motion with the spring compression. The return stroke takes place at the constant speed of 180 feet per minute; the cutting stroke of the machine may be varied through variable-speed gearing; but although the total range of speed—i. e., from 20 feet to 180 feet—is in the ratio of 9 to 1, yet no adjustment is necessary throughout this range, and there is no difference in the accuracy of reversal.

Should the machine be driven by

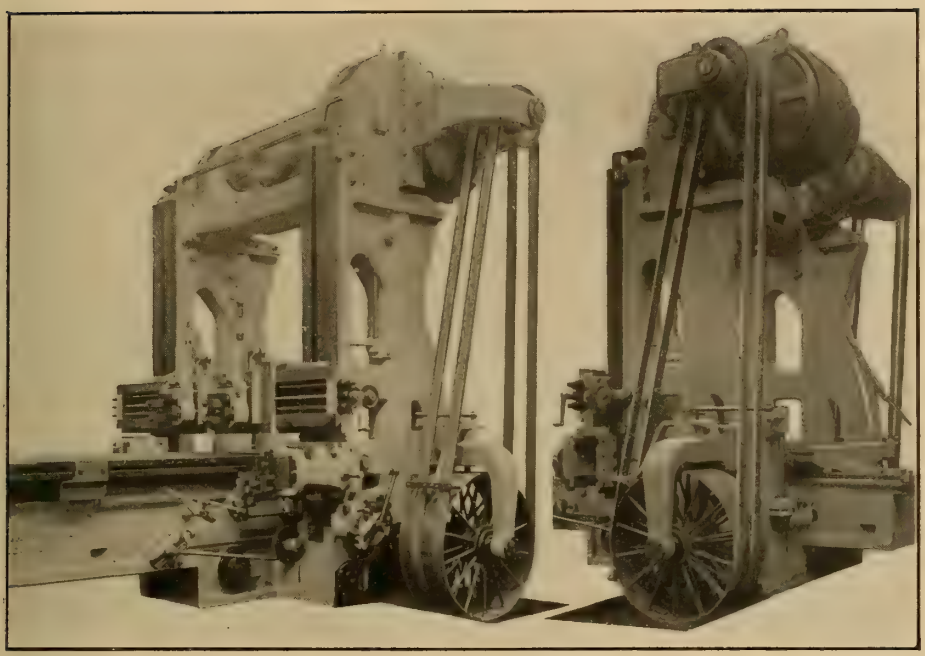
an electric motor whose full load output is absorbed by the maximum cut permissible, then the machine will not impose an overload at the moment of reversal, the net result during maximum cuts being a good load factor.

It will have been noticed that the last-mentioned machine, in common with several others referred to, had means provided to vary the cutting speed. This has become a feature of importance on all planers having pretense to be modern machines. A planer may be called upon to work on different kinds of material, of all hardnesses, and with tools of all qualities. All sizes of cuts may have to be taken; all kinds of finished surfaces may have to be produced. The work itself may be of all grades of stiffness, and of any weight. All these different conditions call for a planer which should be flexible. It should be possible to plane slow or fast, and do this without spending much time in changing the drive.

Mention has been made of the Sellers and the Chandler machines, in which the change gearing is in the final drive. In many makes, as in Fig. 15, a gear box is carried above the machine, and thereby forms a variable-speed countershaft. Here we find again a difference of opinion, and the tendency to maintain the use of belts as giving a smoother and steadier drive than gears. This is exemplified in Redman's patent four-speed countershaft, Fig. 16, in which two shafts are used, driven by a wide belt running on four-step cones. A special shifting device enables the belt to be thrown from one step to another by the simple movement of a hand wheel. The first-motion shaft runs at a uniform speed and carries a pulley to drive the quick return motion. In Fig. 17 is illustrated a machine made by Messrs. Armstrong, Whitworth & Co., Ltd., Manchester, which is arranged with two motors, and these form in themselves a countershaft, or rather two countershafts, the great advantage of the use of two motors in this manner being that a constant speed of return may be used and a speed variable through very fine steps used on



HIGH-SPEED PLANER WITH SPRING BUFFERS. JOSHUA BUCKTON & CO., LTD., LEEDS



PLANING MACHINE DRIVEN BY TWO ELECTRIC MOTORS. ARMSTRONG, WHITWORTH & CO., LTD., MANCHESTER

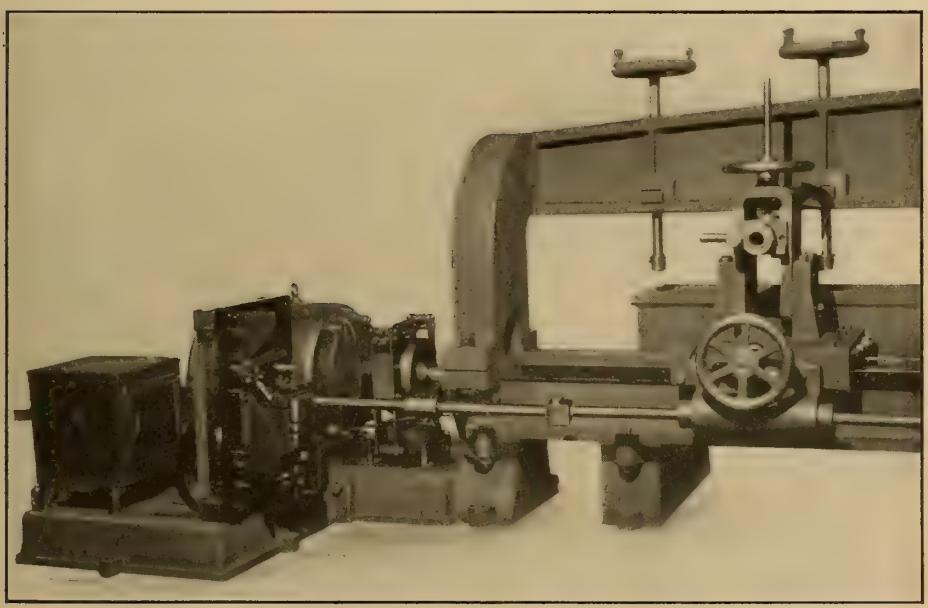
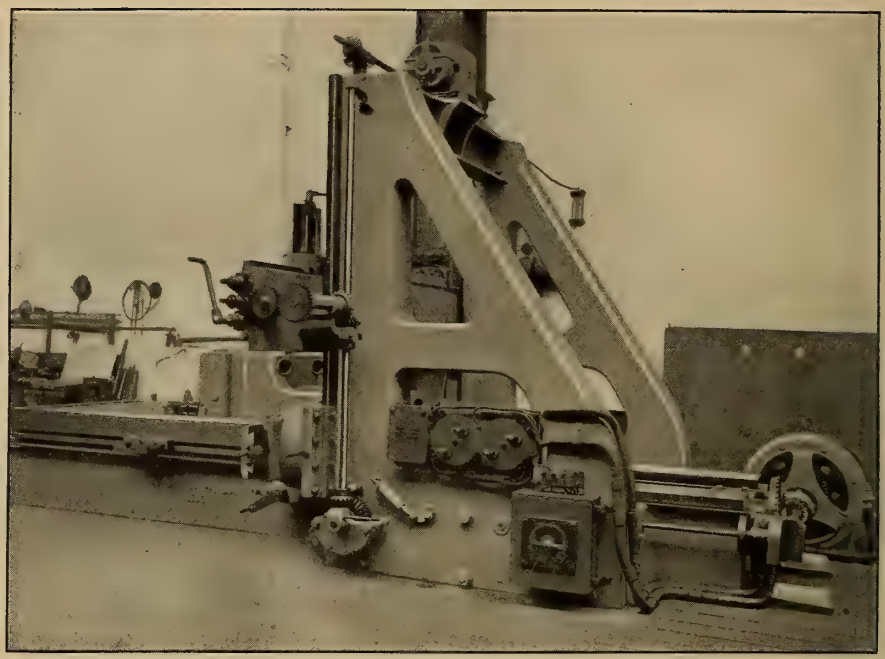


PLATE-EDGE PLANER WITH REVERSING ELECTRIC MOTOR COUPLED DIRECTLY TO THE DRIVING SCREW.
JOHN STIRK & SONS, HALIFAX



ARMOUR-PLATE PLANER DRIVEN BY VICKERS AUTOMATIC REVERSING MOTOR

the cutting stroke. This machine is rack-driven, and has a capacity of 5 feet square. It is capable of taking cuts with two tools, each taking a cut ⅜ inch deep with a ⅛-inch traverse at a speed of 50 feet per minute. The cutting speeds provided for are 25 to 75 feet per minute, and the return speed is 120 feet. The belts pass down either side of the machine, which balances the machine and reduces the overhang of the pulleys. The motor on the right-hand side is the main drive for the cut, and has a variation in speed of 300 to 900 revolutions per minute. The far motor is for the quick return, and runs at 800 revolutions per minute. Both these motors always run in the same direction, and are fitted on a slide which can be moved on the face of the brackets on the top of the cross-stays, and in this way be used as belt tighteners, the motors having a considerable amount of movement vertically for this purpose. Two belts are used for the cut and two for the return, the object being that two belts are more easily moved than one wide belt, and the effective pulling power is equal to the width of the two.

The use of a variable-speed motor opens up another possibility, viz., that by the use of an automatically operated rheostat the motor may drive at a slow speed for the commencement of the cut and immediately accelerate in speed, returning to slow speed at the end of the stroke, thus doing away with the problem of stopping and starting a large momentum. This constitutes one of the best combinations in planer drives.

There have been many attempts to obtain a reversing motor drive, with more or less success. The Vickers drive is probably one of the best. With this there are three switches in the controlling device, and the motor is of the variable-speed type, with a range of speeds of 300 to 900 revolutions per minute.

Of the three switches, two are acted upon automatically by the stops on the table coming in contact with a

tumbler arrangement on the left-hand switch, and this, in turn, by means of chain, acts upon the middle switch, these two switches reversing at the same time.

The third switch is acted upon by means of gearing from the table, and is provided with a slipping device. It is the first motion, on the reversing of the machine, that cuts out this particular switch.

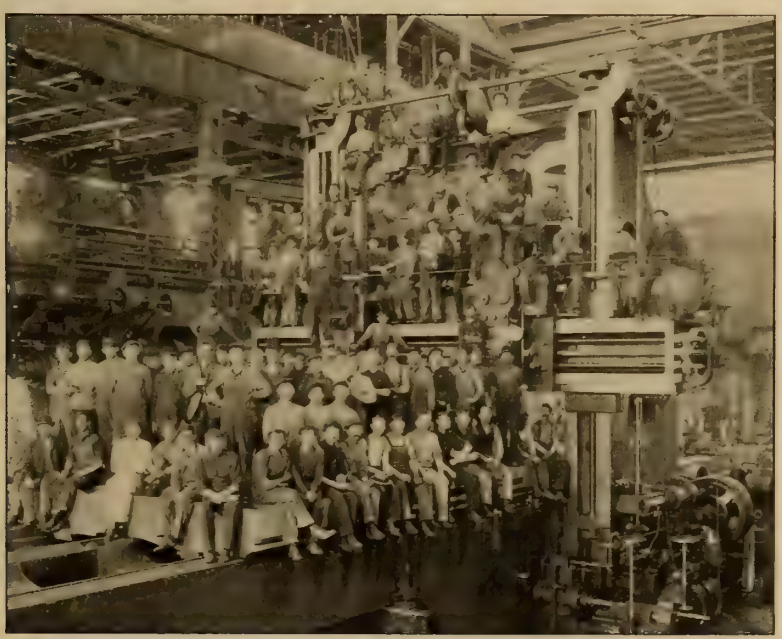
On the cutting stroke the motor runs at its slowest, or any suitable speed, and at the end of the stroke it reverses automatically. As soon as the reversal has occurred, a resistance is automatically inserted in the field winding, quickly raising the speed to 900 for the return stroke.

At the end of the quick return stroke, immediately before reversal, the field resistance is short circuited, providing a strong field for reversing in, and the motor reverses and makes the slow-cutting stroke, the cycle repeating itself.

Reversing motors, however, up to the present, have not been made which will give the quick returns and pick up the speed as satisfactorily as is essential for them to compete with belt-driven machines.

In ordinary planing machines, in which the cut is not longer than 6 or 8 feet and the speed fairly high, the reversal takes place so frequently and must be done so quickly that not only a good deal of time is lost, as compared with the ordinary belt-driven arrangements, but also a considerable amount of energy wasted in continually stopping and re-starting the motor, and to this must be added certain difficulties which are bound to occur with the necessary switch gear and electrical connections.

In the illustration, Fig. 18, which shows a portion of a plate edge planer made by Messrs. John Stirk & Sons, Ltd., of Halifax, the motor is a constant-speed machine, and is coupled directly onto the driving screw. In order to bring the motor quickly to rest, at the end of each stroke an electric brake is attached and operates on the coupling. On



GIANT PLANING MACHINE BUILT BY THE NILES-BEMENT-POND COMPANY, NEW YORK

this type of machine cutting takes place on both strokes, and the drive has proved very effective.

For machines as in the illustration, there is some advantage in using a reversing motor. Then the mass of the moving parts is, comparatively speaking, light, so that the energy used in acceleration is small in comparison with that used in actual cutting.

The points to be taken into consideration are the weight of the moving parts, the length of travel and the number of strokes per minute. If the weight is small, the length of travel great, and the frequency low, then reversing motors can be used and advantage taken of the absence of belts and other forms of gearing.

NOTES ON COMBUSTION

By Nisbet Latta

IN the cosmic development of the world Nature has set a line or zone of demarkation between man and beast, the definition of which is fire. It is the essence of civilization, one of the ancient elements of existence.

In all probability fire was discovered by accident, and evidently by man in his most primitive state. The use of fire, by one of those strange incongruities of cosmic growth, has retained more nearly its elemental and primitive form than any other of the essentials to life, existence, and the industrial activity upon which the life on our planet is dependent.

While measurement has been integrated to the fractional part of a wave length of light and mathematics and physics have reached a development of almost absolute determination, yet the usage of fire, so necessary to human existence and most materially affecting the economic life of society, has remained in a state of primeval crudity, practically unchanged since its inception, and the wanton waste of the world's most valuable resources and fundamental wealth continues in a manner entirely incommensurate with the economical development of our social and industrial life. A realization of this, however, is being brought about, and a sudden and abrupt awakening has come.

This is largely due to the work of the geological and mining surveys of many of the manufacturing nations, and to the fact suddenly brought home that their resources are limited, and that the waste of previous years has made inroads far beyond expectation. It is a fact that the day must inevitably come, and may be said to be almost in sight, when, at the present rate of demand plus the expanding demand-curve of an increasing population, the supply of combustible resources will be practically exhausted.

More than twenty-seven years ago Sir William Siemens, awakening to this situation, said: "I am bold enough to go so far as to say that raw coal should not be used as fuel for any purpose whatsoever, and that the first step toward the judicious and economic production of heat is the gas-retort or gas-producer, in which the coal is converted either entirely into gas or into gas and coke, as is the case in our ordinary gas works."

The growth of this belief has been exceedingly slow, but it has been proceeding at an accelerated rate. The increased cost of coal in the last few years is a potent factor in the situation, increasing the cost of this heretofore (relatively) cheap fuel, which, it formerly appeared, hardly justified the expense of installing economical or regenerative apparatus.

The recent congress which considered the preservation of national resources has focused and summarized the attention of the industrial world upon the urgent necessity of the issue, and it is safe to say that from now on an active interest will be taken upon one of the most important features in all social and industrial economy—that of efficient and economical combustion.

Up to the present date the most economical method of utilizing heat is by the aid of the gas-producer, bet-

ter termed, perhaps, two-stage combustion. This operation is now so widely known that a detailed description is unnecessary. The reason for its efficiency, however, is perhaps less clear in the public mind.

The efficiency of two-stage combustion depends principally upon three functions, namely, (A) the ability to recuperate waste heat; (B) the ability to deliver the heat at the most effective point of application or to distribute it uniformly and without localization over any reasonable given area; (C) to perform combustion without an excess of air (more than the chemical quota) or over-ventilation, thereby "robbing" the fire of the sensible heat of the effluent gases and undissociated air.

There is also another reason which, although hardly an exclusive function of two-stage combustion, is rarely found in the working of the direct-fired furnace, namely, complete combustion of the fuel. The circulation in a direct-fired furnace is usually so rapid as to carry off the volatile portions or products of distillation beyond the ignition zone before ignition takes place. Passing beyond this heat-area or zone at a rate greater than that of its flame propagation, these gases reach a lower temperature area, and, failing to ignite, escape unconsumed, causing a considerable loss.

In furnace work, or in industrial heating operations other than power, there may be said to be two classes of work. In the first class may be placed boiler-firing, forging and tempering of metals. In the second class may be placed practically every other class of industrial heat application.

In the first class gaseous firing is relatively inefficient, by reason of the fact that intense localization of temperature can hardly be said to be a disadvantage, and also because the circulation of the water tends to distribute the heat throughout the whole boiler in a fairly efficient manner. Moreover, the advantage obtained in the boiler operation due to the convected water currents offsets any theoretical disadvantages of high localization of temperature which may exist.

Again, the gaseous firing of a boiler possesses the disadvantage of bringing the gas, during combustion, into contact with a relatively cool surface, producing "shock," the effect of which is dual. First, the reduction of temperature serves, as before described, to permit a certain portion of the gases to pass beyond the ignition area at a rate faster than their flame propagation, and, consequently, to escape unconsumed. Second, the sudden change in temperature tends to precipitate certain of the carbon and hydro-carbon compounds, with the resultant formation of soot and lampblack, which is seldom consumed completely, and is most objectionable because of its insulating character. The ideal design for the gaseous firing of the steam boiler would be an arrangement based upon the reverse-current principle, which is found most satisfactory in gas engineering for all forms of heat-transference work. In other words, the hottest gases or point of combustion would, under this arrangement, come in contact with steam, while the effluent gas and products of combustion would preheat the water and bring it up to ebullition.

This arrangement has been very successfully carried on in laboratory experiments, but the physical construction of the modern boiler will not permit such an arrangement in practice. The tube-sheets, tubes, etc., are unable to withstand high temperatures where not protected by a water content or cooling action, this being the reason, of course, that the water leg of the boiler is usually brought in closest contact with the highest point of temperature in the furnace.

Although for the several reasons named, and others, two-stage combustion is less effective in the production of steam (relatively speaking)

than that of any other heat-productive operation, there are instances where its use is altogether satisfactory, and even in cases essential to commercial service.

These cases occur more particularly in the use of low-grade bituminous fuels, in which may be classed lignite and peat, different varieties of culm, and, in fact, nearly all of those fuels whose thermal value is less than 10,000 B. T. U. per pound.

There are several reasons for this condition of affairs, among which, first and foremost, is the large volatile content of such fuels in proportion to the fixed carbon; in combination with this their flame and heat propagation is exceedingly fast. The result of this combination is that the volatile matter, constituting the binder of the coal, quickly distills out at an early stage of the combustion, the gases moving with extreme rapidity, faster, in fact, than their flame propagation, a large percentage escaping unburned. The residual carbon and ash being left without a binder, tend to clog up all the draft with a finely-powdered mass, the density of which is nearly impenetrable; hence a condition of mass action occurs, whereby the residual carbon is insulated from any incoming air and remains uncombined, resulting in a large fuel waste, due to carbon thus unconsumed, also choking the grates and causing a general irregularity of combustion.

Again, the large ash content of these low-grade fuels tends to stop the grate voids, either completely or partially (where such are small), in the former case stopping combustion and in the latter case creating clinker, due to a concentration of combustion in spots, causing a blanking effect and a baffling or diverting of the draft into channels. To obviate this, either grates with large voids must be used or the natural angle of repose of the fuel utilized. Were this done in direct firing, the result would most likely be combustion with an excess of draft, highly uneconomical; or, should the draft be restricted or throttled by dampers to a sufficient extent to compensate, there would be a lack of circulation, retarding or blanketing combustion. Hence it will be seen that, for the utilization of low-grade fuels, it is essential to arrange some method of combustion which will recuperate not only the volatile matter which is so rapidly liberated, but it is also necessary to control the draft in such a manner that the fuel may be decomposed without an air excess. It is also possible to a great extent, especially where gas is to be consumed in furnaces, to decompose coal at a temperature below the fluxing point of fusible ash, thus preventing clinker, a condition impossible of attainment in direct firing.

As a second item in the first class, forging and tempering metals has been mentioned, inasmuch as these operations depend entirely upon a localized heat; but, even so, it is questionable whether or not some chemical or metallurgical advantages are not to be had from the use of gaseous fuel. This is principally because the heat obtained is more uniform in its nature and the chemical elements of combustion are more nearly regulated; also, because there is greater freedom from impurities in metallurgical combination.

Under the second class we find practically all of these industries in which it is necessary to apply heat to certain material, vessels or containers, instead of bringing said material or containers to the heat.

It would be difficult to estimate the advantage gained in obviating the loss due to localization of temperature; that is to say, the production of heat, a large portion of which is useless and lost through radiation, conduction and static causes at a point where it practically performs no work, and only a minor part of which must be transported through the inefficient means of conduction, radiation, etc., to its actual field of labour, this latter for the most part

being accomplished by the very ineffective medium of the products of combustion of low specific heat.

As an example of the second class, perhaps no better illustration can be cited than the manufacture of cement and lime; and an outline of the possibilities of complete regeneration or heat recuperation in the calcining of the former may be herewith given.

In the modern practice of producing Portland cement in the United States the material is practically all burned in a rotary kiln, usually fired by the burning of a flame plume of pulverized coal, axially with the kiln; but sometimes oil and natural gas are used. The raw materials used in the manufacture may be divided into three groups, as follows:

First Group.—This consists of what are called cement rocks, from their having been formerly used in the manufacture of natural cement. They have nearly the composition of Portland cement, and with the lime, alumina and silica already in combination to some extent. To these rocks is added usually enough limestone to produce cement of the proper analysis, and this mixture is dried, ground and fed into the rotary kiln.

In the second group may be placed a mixture of limestone and silicious clay, dried and ground and fed into the rotary kiln. In burning this mixture, the water of hydration must be dissociated from the clay. The mixture must be raised to the dissociation temperature of limestone, i. e., 900 to 1,000 degrees centigrade, the carbonic acid must be then driven off and the resulting lime and baked clay brought to the temperature at which sintering takes place—about 1,300 degrees centigrade. At this temperature combination of the lime with the silica takes place, forming, among other compounds, tri-calcium silicate ($3CaO, SiO_2$) and di-calcium aluminate ($2CaO, Al_2O_3$), which are considered as the active substances in cement. (Vide U. S. Geol. Survey.)

The third group consists of marl, which is finely divided calcium carbonate, being the remains of sea-shells or fresh-water shells, and with this is mixed enough clay and sand to give the proper proportions of lime, alumina and silica; and this mixture is ground wet into a slurry and fed into the rotary kiln in a semi-liquid form, and is there dried and burned.

In the mixtures of the first group the amounts of lime combined with the silica and alumina and the amount combined with the carbonic acid to form limestone are quite variable, so that the amount of heat necessary to produce cement from this mixture differs in each case and cannot be accurately determined until all the elements of the mixture are analyzed.

In the third group the amount of water is so great and so variable that the fuel requirements cannot be determined until the amount of water present is known.

In the second group, however, the constituents are assumed to be pure, and these will be selected as the mixtures on which the heat determination will be calculated. We will assume that the theoretical cement produced is to have the following composition: Lime (CaO), 68.25 per cent.; silica, 19.72 per cent.; alumina, 11.92 per cent., corresponding to 3 ($Ca_3Si_2O_5$) and ($Ca_2Al_2O_3$).

All the other constituents found in commercial cement are accidental impurities, and it is well settled that they do not improve the cement, and most of them must be guarded against lest any excess impair the quality of the product.

To produce a cement of this quality requires that the following ingredients be used in the proportions given:

Limestone ($CaCO_3$)	121.2 kg.
Clay ($Al_2O_3,2SiO_2, 2H_2O$)	32.0
Sand	4.8
Total weight of mixture	158.0 kg.

Therefore, 158 kilogrammes of raw mixture will make 100 kilogrammes of cement. The operation may be divided into two stages, and

the heat requirements will be here computed for the two operations of calcining and clinkering, the first of these consisting of heating the mixture to 900 degrees centigrade, thus dehydrating the clay and decomposing the limestone.

The heat requirements for producing calcines are as follows:

For dehydrating the clay there will be required 1,218 calories per gramme of water dissociated from the clay—H_2O = 4.5 kg. (Richards, V. II., p. 205). For dissociating CO_2 from limestone, there will be required1,026 calories per kilogramme of CO_2. For heating the charge, it will be assumed that the specific heat of the mixture, at the lower temperature, is about 0.25.

We then have: 158 — 4.5 = 153.5 kg. × 0.25 × 900 = 34,537 calories for heating; 4.5 × 1,218 = 5,480 calories for dehydrating clay; 121 kg. $CaCO_3$ = 53.2 kg. CO_2 × 1,026 = 54,600 calories for dissociating limestone, giving a total of 94,617 calories for producing calcines.

The heat requirements for sintering are much less; in fact, the exothermic reactions produce one-third as much heat as is absorbed in raising the calcines to the sintering temperature; hence the advantages of dividing the process into two stages. The heat of combination of lime with silica and alumina in cement does not seem to have been accurately determined; but Le Chatelier determined that in the combination of 3CaO, Al_2O_3, $2SiO_2$ there were developed 150 calories per unit of Al_2O_3, $2SiO_2$, and as the silica and alumina exist in about that ratio in the cement, their sum multiplied by 150 calories may be taken as giving the heat produced.

In heating the calcines from 900 to 1,300 degrees centigrade, their specific heat is assumed to be 0.30; therefore, 100 × 0.3 × (1,300 — 900) = 12,000 calories absorbed by clinker; 31.65 (SiO_2 and Al_2O_3) × 150 = 4,747 calories produced, giving 7,253 calories absorbed from fuel.

The total heat units in the clinker as discharged would be as follows: 100 kg. × 0.30 × 1,300 = 39,000.

The above represents the heat requirements, provided that the gases of combustion leave the kilns cold, and the carbonic acid gas from the limestone leaves the kiln at the temperature of dissociation.

Practical working tests with a gas-fired rotary kiln 100 feet long by 6 feet in diameter, burning limestone crushed to 2-inch size, such limestone containing 98 per cent. $CaCO_3$, have shown that it is safe to assume an output of six parts of lime to one part of good gas coal; therefore, 66 kilogrammes of lime would require 11 kilogrammes of fuel, and as there are 66 kilogrammes of lime in 100 kilogrammes of cement, 11 kilogrammes of coal would calcine all of the lime required for 100 kilogrammes of cement.

There remains only the heat requirement for bringing 33 kilogrammes of SiO_2 + Al_2O_3 to the required temperature at which the lime is formed.

SiO_2 + Al_2O_3 = 33 kg. × 0.25 × 900 degrees = 7,425 calories, which would be equivalent to not more than 1 kilogramme of coal per 100 kilogrammes of calcines; therefore, we have 11 kg. of coal to produce 66 kg. of lime; 1 kg. of coal to raise temperature of clay; ½ kg. of coal allowance for losses in heating up clay, a total of 12½ kg. of coal per 100 kg. calcines, or one of coal to eight of calcines.

For clinkering, estimating that the calcines are discharged directly from the primary kiln into the clinker kiln at 900 degrees centigrade, and are heated therein to 1,300 degrees, a rise of 400 degrees in temperature, we have 100 × 0.30 ×400 = 12,000 calories absorbed.

The clinkering operation is exothermic, and, as Le Chatelier has determined that 150 calories are evolved per unit of combined SiO_2, Al_2O_3, therefore 31.65 kg. combined silica and alumina × 150 = 4,747 calories.

Subtracting this from the 12,000 calories absorbed by the calcines in the clinkering kiln, there remain 7,253 calories per 100 kilogrammes to be furnished by the fuel. This represents somewhat less than 1 per cent. of fuel for clinkering.

Assuming 180 tons to be clinkered per day in one clinkering kiln, we have $\frac{180{,}000}{100} = 1{,}800$ kg. of coal, or 1 per cent.

There remain 39,000 calories in the discharged clinker, and assuming that 33⅓ per cent. of this heat can be taken up by cooling with air and supplied to the primary or calcining kiln, 13,000 calories would be furnished per 100 kilogrammes, equivalent to 1½ kg. of coal to be subtracted from the 12½ used in calcining, which gives 11 kg. of 11 per cent. of fuel, or one of coal to nine of calcines.

Assuming an efficiency of only 25 per cent. in the clinkering kiln, or 4 kg. of coal per 100 instead of 1, we have 1,800 kg. $\times$ 4 = 7,200 kg.

This is 4 per cent. of the fuel consumption, or 4 kg. per 100 to be added to the 11 kg. required for calcining, which gives 15 kg. coal to 100 kg. cement, or one of coal to 6.6 cement.

A regenerative system is capable of utilizing 84.2 per cent. of the total heat of the gas, and the producer should have an efficiency of 80 per cent., thus giving an efficiency of 64 per cent. for the combination of producer and kiln, not allowing for radiation losses. Allowing 14 per cent. for losses by radiation, which seems ample, gives an efficiency of 50 per cent. for the clinkering kiln outfit. If this result is realized, the process would yield 7.69 kgs. of cement for each kg. of coal consumed.

This effects a saving of more than one-half of the present fuel consumed under average direct-firing practice, or an increased efficiency of over 100 per cent.

The second example, that of lime, is particularly interesting. It is a paradoxical fact in the calcining of limestone that the softer the stone, the more difficult it is to burn, and the greater the amount of fuel required for its complete calcination. This is again due to certain conditions of mass action; that is to say, at a stage quite early in the process, and before all of the carbon dioxide is driven off by the action of the heat, the stone "fines," forming a dense granular mass so compact as largely to exclude the passage of draft and escaping gases, and some extent to insulate large portions of the charge from the action of heat.

It is obvious that where calcining is performed by direct firing with high localized temperatures, it necessarily follows that those portions of the charge immediately adjacent to the furnace may be considerably overburned. This condition is materially reduced where the combustion is gaseous, by reason of the voluminous flame and the permeating powers of the air-gas mixture, combustion taking place within the limestone charge itself, instead of in the furnace, whence it would only be reached by radiant heat, an inconsequent amount of conducted heat and the sensible heat of the effluent products of combustion.

In the opinion of the writer, practically all of these objections are overcome by the use of the rotary kiln in lime manufacture, this offering a very perfect calcination, due to the exposure of each integral part of the limestone to the action of the heat, and by its rotary motion permitting each side of the limestone fragment to become exposed in turn. It also permits the utilization of spalls and calcines with equal efficiency, practically every form of lime carbonate.

To utilize the rotary kiln, it is, of course, necessary to crush the limestone, and to this there seems to be some trade prejudice, the product of years gone by, so remote as to have lost any definite reason for its

existence, save a general idea that the pulverized limestone has an additional tendency to air slack. Opposed to this, however, is the fact that lime in lump form is apt to be overburned at the surface, while not completely calcined at its centre, hence making the lime dark in colour, slow to slack and of less strength.

From a commercial standpoint (which, after all, reflects the true worth of the matter) it is certain that the rotary kiln yields some six pounds of lime per pound of coal fuel used, and that even the old-fashioned shaft kiln yields on the average five pounds of lime per pound of coal fired, a result double in efficiency to that obtained under conditions of ordinary direct-fired shaft-kiln practice, using forced draft or inspirating with steam.

Any efficiency reflected in the foregoing examples is undoubtedly due in main part, first, to the ability of complete combustion with the theoretical complement of air (in practice, with gaseous firing this need not exceed 10 per cent., while in direct firing the air excess may run from 300 to 700 per cent) and to the ability to recuperate waste heat and return it into a potential, work-performing state.

Again, as cited, the ability to distribute the heat most effectively, as opposed to localization, is most important. Butterfield notes a discrepancy of temperature within the field of a furnace heated by direct firing, showing an extreme difference of 400 degrees. This difference under conditions of good design with gas firing will not exceed 200 degrees centigrade.

Euchene found the maximum temperature of a direct-fired furnace to be 1,375 degrees centigrade, the products of combustion leaving the furnace at 975 degrees centigrade, the heat duly reflected by this difference of temperature or "drop" being approximately 24 per cent. In a regenerative setting the maximum temperature was 1,250 degrees centigrade, and the products of combustion, escaping to the recuperator at 1,050 degrees centigrade, showed a heat duty of 13.10 per cent.

This would apparently show a thermal advantage upon the part of the direct-fired furnace, the total heat abstraction being greater upon its part. However, it only indicates a concentration of heat abstraction, such abstraction being unequal and localized; for Euchene further notes, upon a Siemens alternating recuperative set, that in traversing the recuperator the temperature fell from 1,050 degrees centigrade at the outlet of the furnace to 600 degrees at the outlet of the recuperator. Hence the total drop in the temperature in the furnace plus the recuperator combined (which, from an economic standpoint, must be taken as a whole) was from 1,250 degrees centigrade to 600 degrees centigrade, a total abstraction of 650 degrees showing a heat duty or thermal efficiency of 43.3 per cent. Even this terminal temperature is excessive, and could be materially reduced by additional heat-absorbing and regenerative surface, with commensurate economy. Taking these figures, however, not only does this comparison show an efficiency *per se* more than double that of the direct-fired furnace, but the abstraction of the heat is more gradual and uniform, the cycle possessing less irregularities or severe variations.

When it is taken into consideration that the coal bill of the United States is greater than the volume of business done by all the railways, steamship or transportation lines in the country, some idea may be gained of the economical possibilities in adopting a method of combustion which in every way practically doubles the efficiency of primitive methods of direct-firing and its consequent waste, halves the cost of fuel, and doubles the life and value of the greatest source of wealth, conserving the very existence and growth of the human family itself.

MODERN DREDGING APPLIANCES FOR WATERWAYS

By J. A. Seager

AT the present time there is beginning to be evidenced a movement in favour of the fuller recognition of the value of waterways, including not only the docks and quays adjacent to the open sea, but also the region on a river which lies at some distance away from the coast. There is no doubt that the system of canals and rivers affords a means of cheap transit for goods which is not nowadays properly utilized. The advent of the railway caused a great decline in the uses to which canals were put, and their maintenance has, therefore, to a large extent degenerated. In some countries, however, transport by water has been maintained to a considerable extent, and there is no reason why, with an adaptation of the numerous electric tractor systems suitable for barge towing, the waterways of England and America should not, as auxiliaries to the railways for heavy goods transport, become as important as they have been in the past. This is especially important in view of the modern tendency of manufacturing firms to move out into the country, where expenses are low.

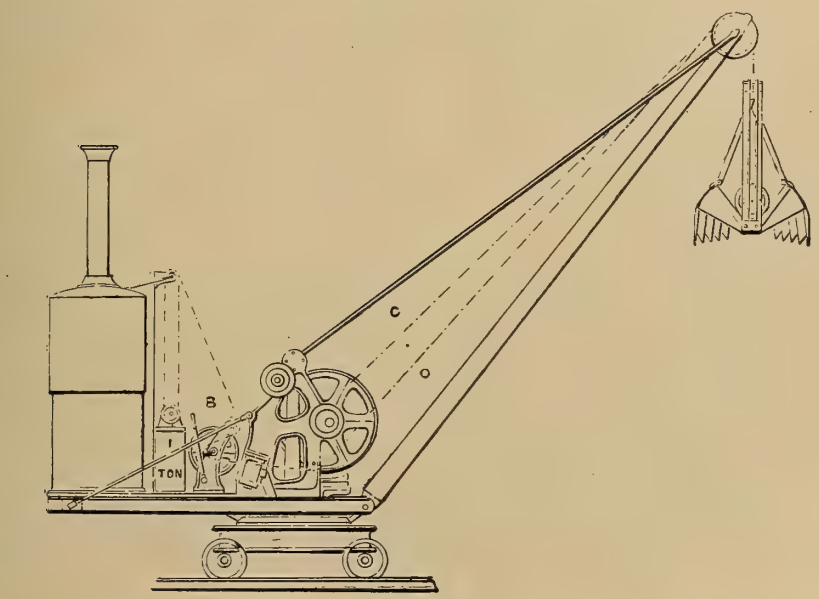
One important consideration, however, affects this problem, a consideration which, in the event of the revival of the canal and river haulage, to a great extent will have to be faced, in view of the many years of neglect which have supervened since the time of adequate use of our water facilities. This is the question of clearing the waterways of accumulations of silt, and, in some cases, deepening and widening them, in order to admit of the passage of boats of larger capacity than were used in the earlier days. It may, therefore, be interesting to examine the dredging appliances which are available for this purpose, the sphere of the study being limited to the function of dredgers in opening up and maintaining a waterway and the port in connection therewith.

The ancient method of dredging was by means of the "Bag and Spoon" barge, which consisted of an ordinary barge fitted with a small manual hoist on one side and balance weights on the other, so that the boat was kept trimmed. The dredger itself consisted of a large leather bag kept open by a heavy iron ring called the "spoon" and fitted to the end of a long wooden shaft. A rope was attached to the iron ring, and by means of the hoisting gear the bag was dragged along the bottom of the river and hoisted to the deck level, when the spoil was tipped into the hold of the barge. In order to make certain that the bag at each haul was properly filled with spoil, artificial weight was applied when the bag was on the bottom of the river by temporarily lashing the projecting end of the staff to the side of the barge. The capacity of the bag varied from a half to one cubic yard, and in order to operate it a gang of from five to eight men were employed. The total dredging capacity of such an apparatus was about 100 tons per day, and this method is still occasionally used on small work.

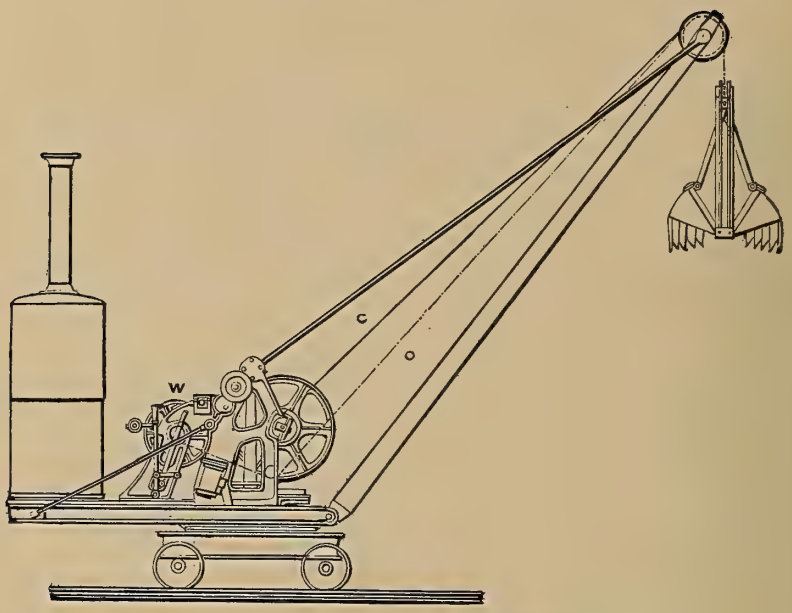
As a rule, however, "Bag and Spoon" dredging has been generally superseded for general work by "grab" dredging. In this system a grab, consisting of two scoop-shaped

metal plates hinged at the top and connected through a chain and toggle gear, is used in connection with a steam crane fixed on the barge, which is made either of wood or steel. In operation, the grab is dropped into the material to be excavated, and when a lift is given to the crane the two sides automatically close together, enclosing a quantity of the spoil, which is then lifted and either transferred to the dredger barge itself or to auxiliarv hopper barges moored alongside.

The types of grabs that are used vary in construction with the nature of the material to be displaced. For soft mud the bucket type is used, consisting of plain shell-like sections closing together with a very tight fit, while steel prongs or tines are fitted to the scoops when stiff clay or rock has to be dealt with. A special means of operating the grab has been developed by Messrs. Rose, Downs & Thompson, Ltd., of Hull, two chains or steel ropes being employed in their Kingston patent dredger, one for closing the grab and lifting, the other for opening the grab and lifting it while open. This second rope is worked by an auxiliary winch, thus enabling the grab to fall free into the spoil and to be opened under water when necessary. This is an advantage when, for example, the grab gets fast on old piling or other obstructions. The two line illustrations show the difference between the ordinary and the Kingston grab. In the ordinary, the bucket is suspended by two chains, the closing or hoisting chain *C* and the opening chain *O*, the latter being held in tension while the grab is being lowered, it being capable of stoppage to allow the dredging to be discharged. This is done by allowing the entire weight of the grab to come on the chain *O*. This chain is connected by a series of sheaves to a counterweight moving on a vertical slide. As the grab is lowered the weight is raised, keeping the grab open by tension on the chain *O*. Since total force exercised on the material to be lifted by the dredger is the weight of the grab plus the energy of descent, it will be seen that in the machine shown in Fig. 2 this must be minus the effect



ORDINARY GRAB BUCKET FOR SOFT-MUD DREDGING



KINGSTON PATENT GRAB. ROSE, DOWNS & THOMPSON, LTD., HULL

of the counterweight, which ranges from one ton to four tons, according to the depth at which dredging is being operated. When the closing chain comes into action the counterweight tends to lift the unclosed grab away from the bottom, and in some cases where the dredger has to pass under bridges the height of the counterweight slide is found to be an objection. In Fig. 3 it will be seen that the opening chain *O* is led to an auxiliary winch *W*. When the grab is lowered to its work both chains run out freely, being kept from overrunning by a brake, and thus the full energy of the falling grab is employed in embedding itself in the material to be lifted. Single-chain grabs for attaching to an ordinary chain require a discharging hook to be attached to the crane head. In operation, the grab falls into the spoil and closes automatically when lifted. In order to empty the grab, it is lifted until it strikes the discharging hook, which then releases the spoil. Grabs are rarely used in connection with manual cranes, inasmuch as the weight of spoil lifted is about a quarter of the lifted load, and steam is the usual power agent.

Fig. 4 shows a 500-ton steam hopper barge of the Kingston patent type, with separate propelling engines and boiler. Two dredgers are used, fixed fore and aft of the hopper well, steam being taken from the main boiler. By means of this type of dredger it is possible to dredge amongst shipping and along dock walls, while in the event of one machine giving out the other can continue working, avoiding any stoppage for repairs.

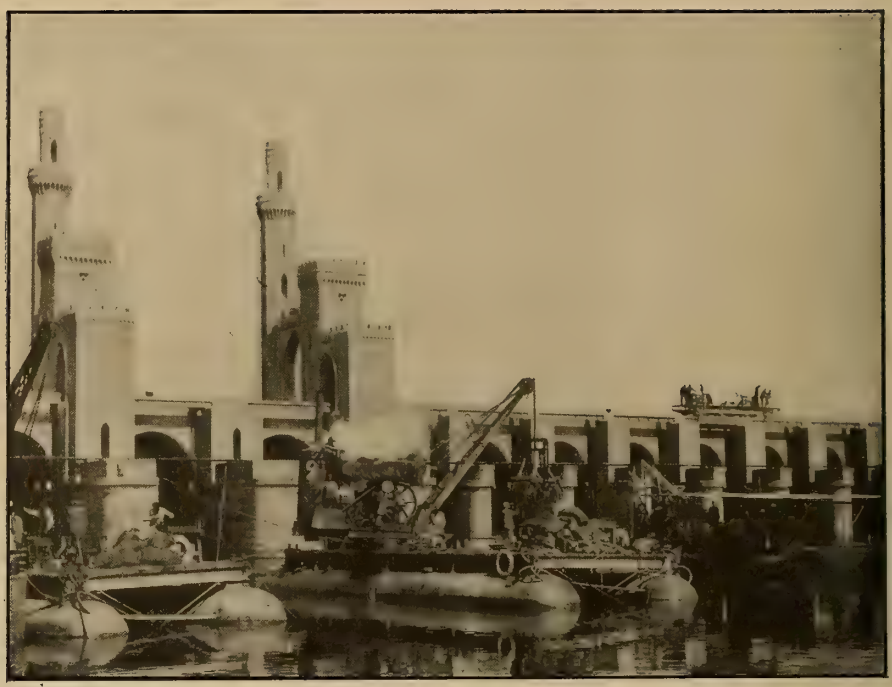
Grab dredgers are largely used for inland work and small harbours, these being often mounted on a barge, which is either towed or self-propelled. A particularly ingenious combination in one of the dredgers of the firm just mentioned drives the propeller through bevel gearing from the crane engines. In most cases the gear is mounted at the fore end of the barge, so that it may cut its own flotation in shallow water. As a further example of the value of this barge type of dredger may be mentioned the Kingston dredgers em-

ployed on the reconstruction of the Lower Barrage on the Nile for three years, under the charge of the Egyptian Public Works Department. These are shown in Fig. 5, and were found useful for many other purposes besides dredging, such as loading barges with stones and blocks of concrete, and also dragging timber out of the plantations on the line of the canal. This system of dredging is an ideal auxiliary to large bucket dredgers which will be described later, inasmuch as it is possible to work in intricate corners. Care, however, must always be taken never to drop the grab on the same spot twice in succession, as otherwise a series of deep holes will be formed instead of a level bottom.

The first power-driven dredgers had an endless chain of buckets working over a ladder suspended over one side. The dredged depth was regulated by varying the inclination of the ladder, and the spoil was carried by the buckets to the top of the ladder, when it was tipped into a shoot and delivered into a hopper barge moored alongside. The side ladder arrangement is somewhat clumsy, and the dredger is not at all seaworthy. In the modern type the ladder is placed in the centre of the boat and works through a well in the bottom of the vessel. It will be found on examination of most modern dredgers for ordinary river and harbour work that they have this well situated in the bow of the vessel, as this gives a more convenient arrangement for the machinery; but where sea-worthiness is very necessary, the stern-well position is adopted, inasmuch as it gives better manœuvring.

As an example of the bow-well type of bucket ladder dredger, probably the *Shieldhill,* a large twin-screw barge loading bucket dredger, built for the Clyde Navigation Trustees by Messrs. Ferguson Bros., of Port Glasgow, may be mentioned as one of the best types. The length

500-TON STEAM-HOPPER BARGE "TIMARU"



KINGSTON DREDGE EMPLOYED ON THE RECONSTRUCTION OF THE LOWER BARRAGE ON THE NILE

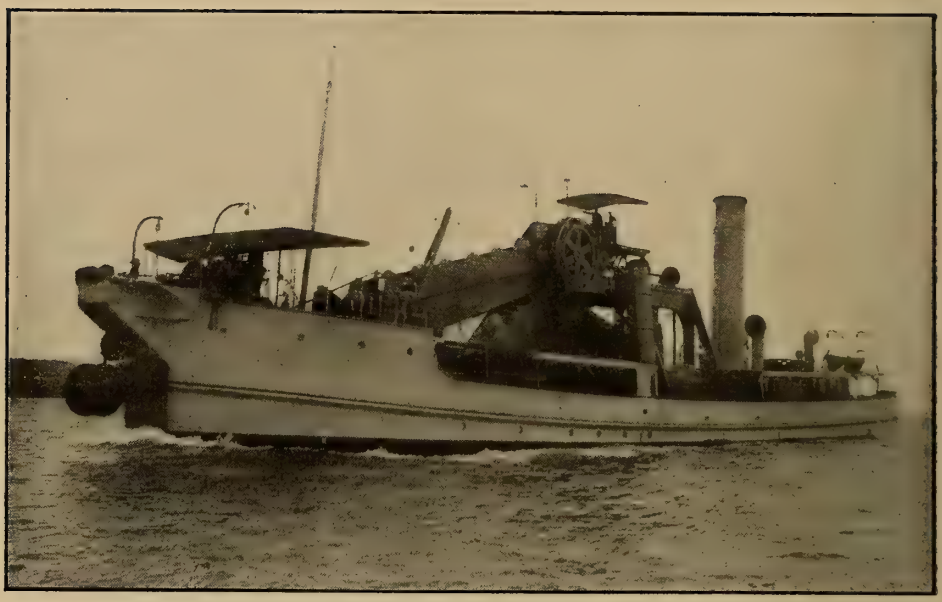
of the vessel is 198 feet, the breadth moulded is 39 feet, depth moulded 13 feet, and the dredging capacity is 1,000 tons per hour from a depth of 50 feet below water level. Steam gearing is fitted at the after end of the engine casing, controlled from the main bridge. A raised forecastle is formed for the purpose of strongly tying the two sides of the vessel across the ladder well, and the bucket ladder projects sufficiently in advance of the hull to enable the dredger to cut her own flotation. This ladder is suspended in heavy bearings, independent of the tumbler, and the lower ends of the ladder are specially arranged to take side thrust. Side shoots are fixed for discharging the dredger material over either side of the vessel into hopper barges, the lifting and lowering of these shoots being worked by a separate vertical engine placed amidships. The two sets of main propelling and dredging engines are of the compound, three-cylinder crank type of 1,100 indicated horse-power, with steam pressure of 130 pounds per square inch, supplied by two multi-tubular marine boilers. The dredging machinery consists of two sets of buckets of different capacities constructed of very heavy material, the smaller set being used for getting out material which, before the building of this type of dredger, was blasted before dredging. A large steam crane is fitted on the deck for overhauling the buckets and for general lifting purposes. The hoisting gear for the bucket ladder consists of heavy iron rope tackle, working in upper and lower sheave blocks suspended from a crosshead, fixed on a box framing structure built into the forward end of the vessel. The lower sheave blocks are connected to the bucket ladder by strong side rods. The wire rope is wound on a large grooved barrel driven by gearing from a double-cylinder vertical engine under the deck, this gearing being controlled by double friction brakes for

holding, lowering or heaving the load, as required. The wire rope is 6½-inch special flexible plough steel, and powerful steam winches are placed at the bow and stern of the boat for manipulating the mooring chains and holding the dredger up to its work. The forward winch has six barrels and the stern winch five, each winch being driven by an independent vertical two-cylinder engine. This is one of the most powerful bucket dredgers which has recently been constructed.

Another example of bow-well bucket dredger ladders is the *Kuantan,* built by Messrs. Fleming & Ferguson, Ltd., of Paisley, to the order of the Crown Agents for the Colonies. This was constructed under the supervision of Messrs. Coode, Son & Matthews, consulting engineers, London, for service at Kuantan harbour, Pahang. She is a twin-screw hopper vessel, designed either to load her own hopper or to discharge into barges alongside. She is rigidly designed, so as to permit of her going out to sea in heavy weather to discharge, a raised forecastle of strong construction tying the vessel and giving the necessary stiffness. The propelling and dredging engines are of the triple-expansion type, designed for a working pressure of 160 pounds per square inch, and so arranged that either set can be utilized in connection with the dredging gear. The driving gear is of cast steel, and is arranged to give speeds suitable for soft or hard material, as desired, with the engines running at a constant speed. The bucket ladder is raised by means of wire rope tackle working in upper and lower sheave blocks suspended from the outrigger at the bow of the vessel.

As an example of the open stern-well type of twin-screw dredger may be mentioned the *General Diaz,* constructed by Messrs. Lobnitz & Co., Ltd., of Renfrew, Scotland. The ladder in this case projects beyond the stern, so as to cut through shallow banks. This type is especially valuable for working in exposed positions, and one dredger of this class

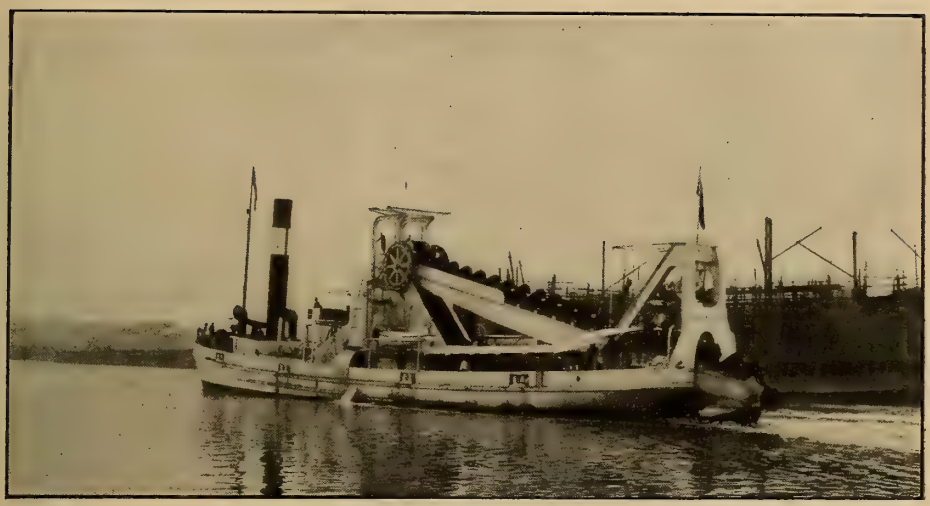
BOW-WELL TWIN-SCREW BUCKET-LADDER DREDGE "SHIELDHILL"



BOW-WELL DREDGE "KUANTAN," BUILT BY FLEMING & FERGUSON, LTD., PAISLEY, SCOTLAND

navigated 16,000 miles around Cape Horn under her own steam, with ladder buckets and other tackle in position. She arrived, after a good passage, quite ready for starting work, no special preparations being required to enable this type of dredger to go to sea. When working on an exposed sandbank a hopper dredger must be used, as the buckets must load into the hold of the vessel. It is impossible for a barge to lie alongside the ship. As soon as a load is obtained, which takes from one to two hours in modern dredging work in sand, the bucket ladder is raised and the dredger steams to the depositing ground, which is always chosen as near as possible consistently with the absence of danger of the sand being carried back into the dredged area. In river work a dredger usually loads into barges moored alongside, a shoot being provided on each side, so that no time is lost in waiting for a barge to be manœuvred into position.

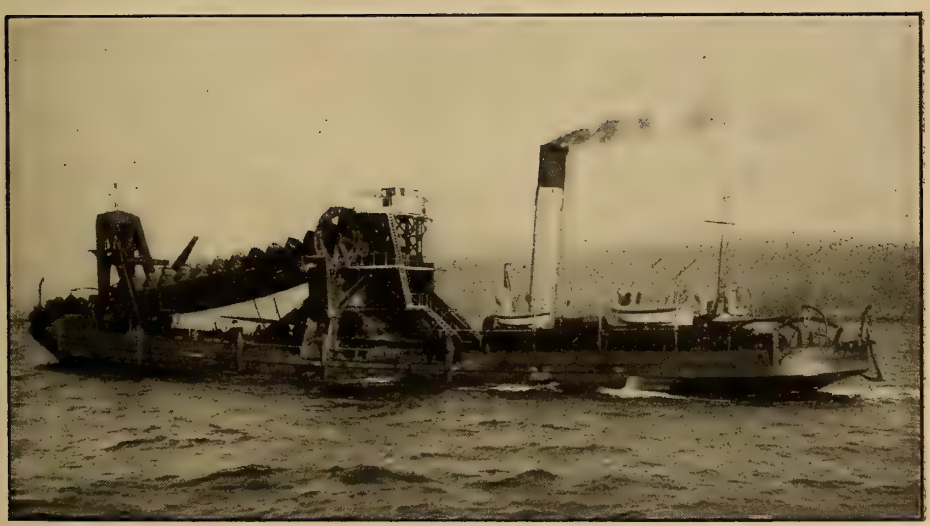
Iron or steel hulls, protected with wood fenders, are now most general; but for most river work, especially where the dredger is likely to take the ground, timber hulls are preferable. The hoisting gear generally consists of steel wire rope and tackle, and oil pipes are fitted for lubricating the bottom tumbler by means of screwing in grease under pressure. The usual means of drive for the bucket chain is by means of cast-steel spur wheels, this drive being always independent from the propelling engines. Two speed ratios are provided by the gearing, so that the engines may always work at the most economical speed, irrespective of the speed of the buckets. The shape and size of the bucket are controlled by the structure of the river bottom, as well as by the power of the engines. It is often found that for an all-round dredging plant two sets of buckets are supplied, one set having large buckets with front sides at an angle of about 65 degrees for sand dredging, and a smaller set with the front sides at 27 degrees for working in rock. A typical rock bucket dredger, built by Messrs. Lobnitz & Co., is shown in the illustra-



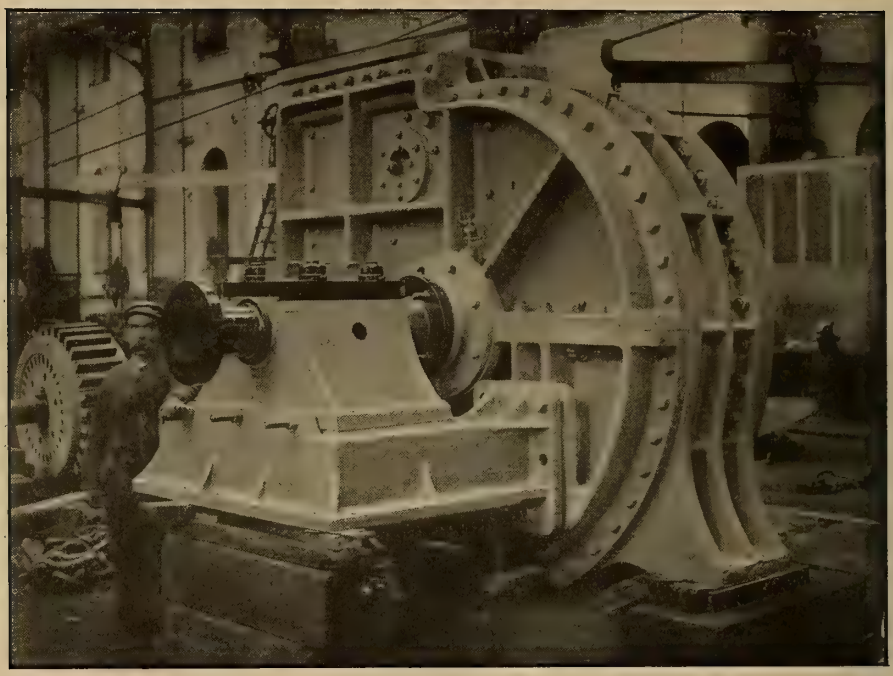
OPEN STERN-WELL TWIN-SCREW DREDGE "GENERAL DIAZ"

tion. Rock cutters, consisting of steel prongs, are sometimes fitted on the bucket chain between the buckets, to break up the bottom and save wear on the bucket lips during the process of dredging.

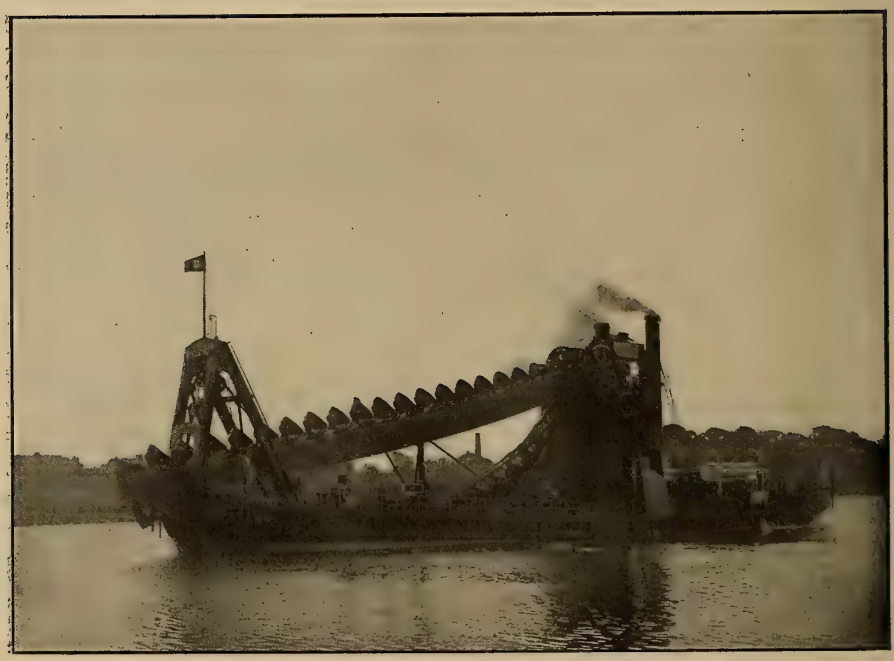
Inasmuch as a large proportion of the obstruction in a waterway is likely to be due to sand, the suction pump occupies a very important place in the present discussion, as the suction dredger is the most recent development for the removal of sand. A large centrifugal pump contained in the dredger is used in conjunction with trailing pipes, which lie along the bottom of the river bed. The percentage of sand in the mixture of sand and water must not be too great, as otherwise the pump will choke and the fluid friction due to the passage of the mixture in the pipe increases



TYPICAL ROCK BUCKET DREDGE, BUILT BY LOBNITZ & CO.

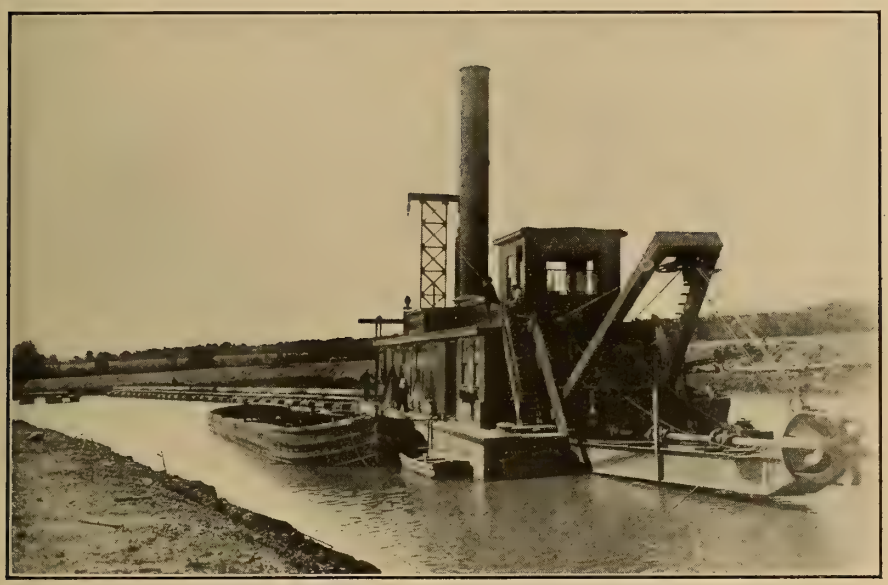


SAND PUMP USED ON BOARD OF THE VESSELS BUILT BY LOBNITZ & CO.



BUCKET-LADDER DREDGE FOR RIVER SERVICE, DESIGNED BY LOBNITZ & CO.

the work on the pump enormously. About the biggest proportion of sand and water which it has ever been attempted to pump is about 40 per cent. The arrangement of the trailing pipes usually adopted is either to place one over each side, or else one large one in a well in the stern of the barge. Most of these dredgers are designed for operating on sand banks, so that hopper dredgers are required. While dredging, the surplus water is pumped out of the hold, leaving only sand. This increases the hopper capacity, but between 1 and 3 per cent. of the sand is carried overboard, as enough time cannot be spared for all the sand to settle out. The illustration shows the type of sand pump which is used on board these vessels as supplied by Messrs. Lobnitz & Co., this being of the centrifugal type, with sufficient clearances for passing the water and contained grit. The sphere of usefulness of these dredgers is vastly increased when they are able to work in clay and similar material. This is sometimes arranged for by placing a cutter on the end of the suction pipe, this being driven by bevel gearing from an engine on deck. The cutters, as used by Messrs. Simons & Co., Ltd., of Renfrew, Scotland, consist of six steel cutters about 4 feet long revolving round the outside of the bottom of the suction pipe. This pipe is then lowered to the bottom of the waterway, and the cutting gear, as it is dragged along, cuts the clay into small pieces, which can be easily dealt with by the pump, the percentage of water admitted being determined by the hoisting gear for lowering the suction pipe.



A BUCYRUS SUCTION DREDGE ON THE NEW YORK STATE BARGE CANAL

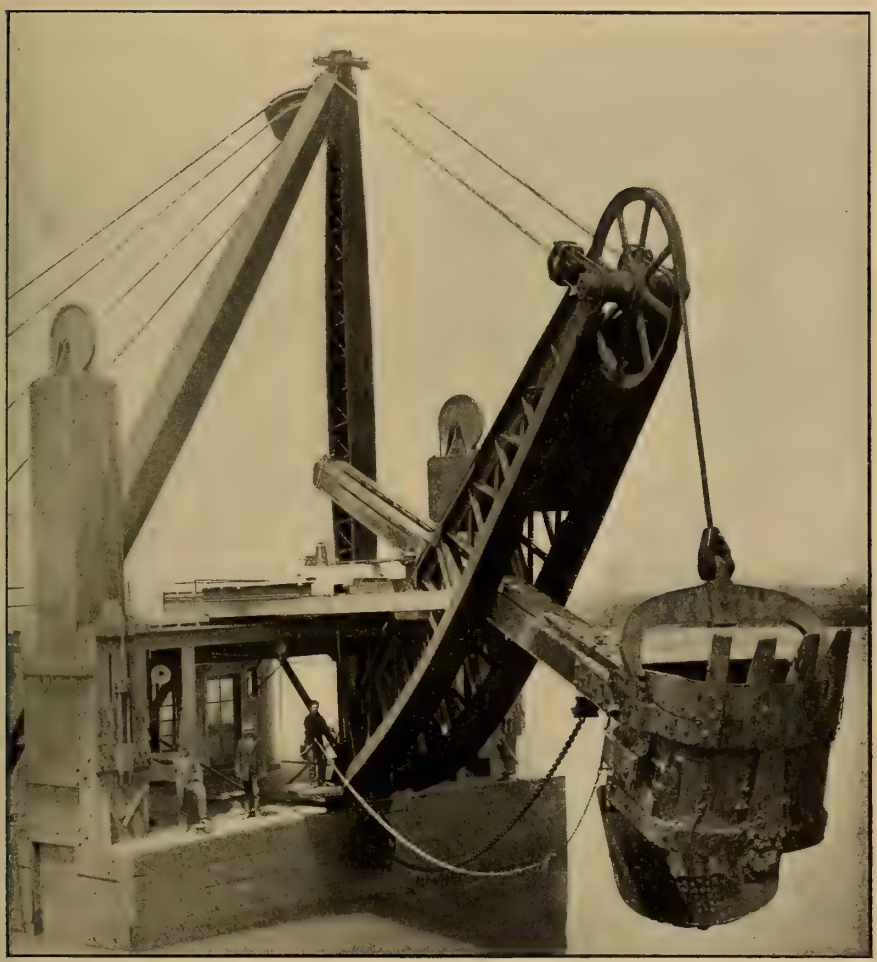
The cutter fitted to the dredger *Jinga,* which was built by Messrs. Simons & Co. for the Bombay Trust, is provided with a single suction pipe working through a sternwell. The cutting gear consists of a large spiral rotary cutter, shaped like a propeller. It has twelve blades, is fitted at the lower end of the suction frame, and is driven through spur gearing. The same firm, in a suction dredger built specially for the Rangoon port improvements, fit very powerful water jets on the underwise of the suction noz-

zle to disturb the hard, sandy bottom. This method, when it can be adopted, is very much more efficient than the use of cutters; but is only suitable for sand. Occasionally vessels are fitted with both dredging buckets and suction pipes to enable them to deal in the most efficient manner with every class of river bed.

It is often desirable to use the dredged materials for the reclamation of land, and in canal work this is almost always done when a grab dredger is used. Where a bucket dredger is employed, the most economical arrangement is to use a long shoot, the spoil after being tipped out of the buckets flowing by gravity along the shoots, as shown in the illustration of a long shoot bucket dredger constructed by Messrs. Lobnitz & Co.

The series of wire ropes supporting the long shoots at various points along its length, and the arrangements for steadying and directing its motion, will be noted in the photograph. Where suction dredging is used, it is possible to deliver the spoil to the land which is to be reclaimed through a long pipe line floated on pontoons. The joints on such a pipe line are always flexible, being made either of copper-riveted rawhide or some special design of universal joint. There is practically no limit to the length of line, as a pressure up to 30 pounds per square inch is sufficient for half a mile. In distances above this it is necessary to place a relay pump vessel about every three-eighths of a mile, in order to work up the pressure again. The power and pressure required depend on the composition of the fluid, which, with sand, is about 13 per cent. of sand and 87 per cent. of water. A light wall is erected around the land to be reclaimed and the tail of the pipe line is placed behind it. It is then arranged that the overflowing water has a long passage back again to the river, so that it may deposit all the sediment which it holds. Hopper dredges are not used in this class of work, as all dredgings are discharged into the pipe line. Where the length of travel for the discharged material is short, an overhead pipe line can be ar-

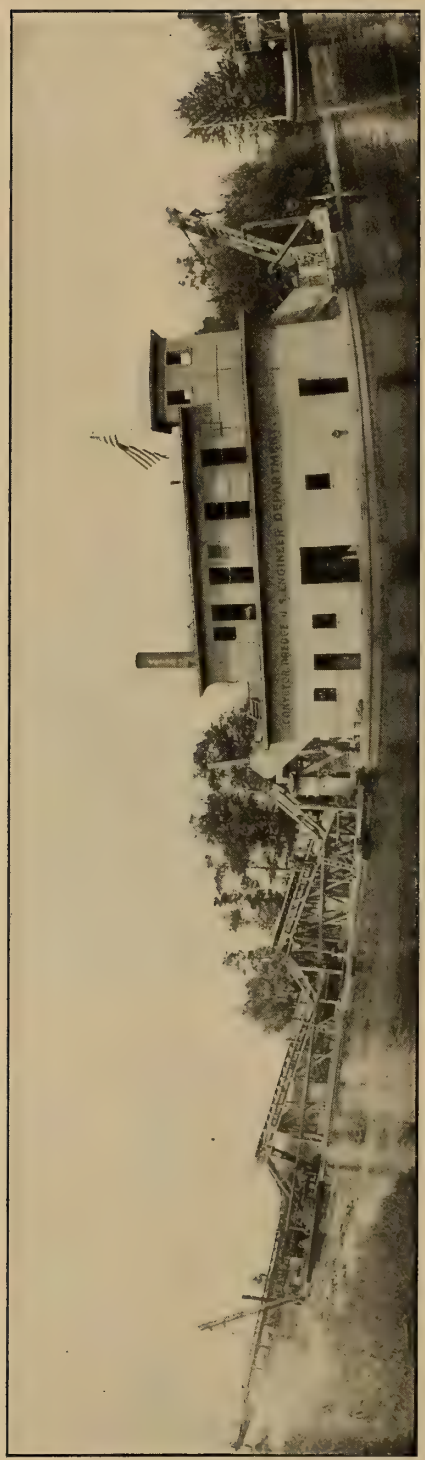
DIPPER DREDGE IN THE HARBOUR OF BUFFALO, N. Y. THE BUCYRUS COMPANY, MILWAUKEE



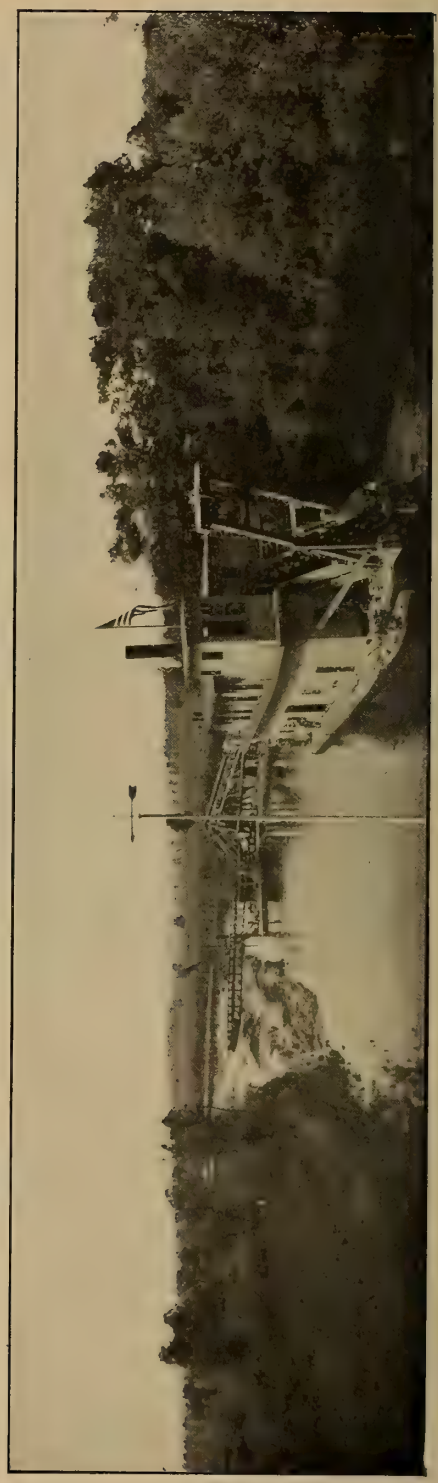
THE 10-YARD DIPPER OF THE BUFFALO DREDGE

ranged with a long shoot suction dredger, this method being used for land-reclamation purposes.

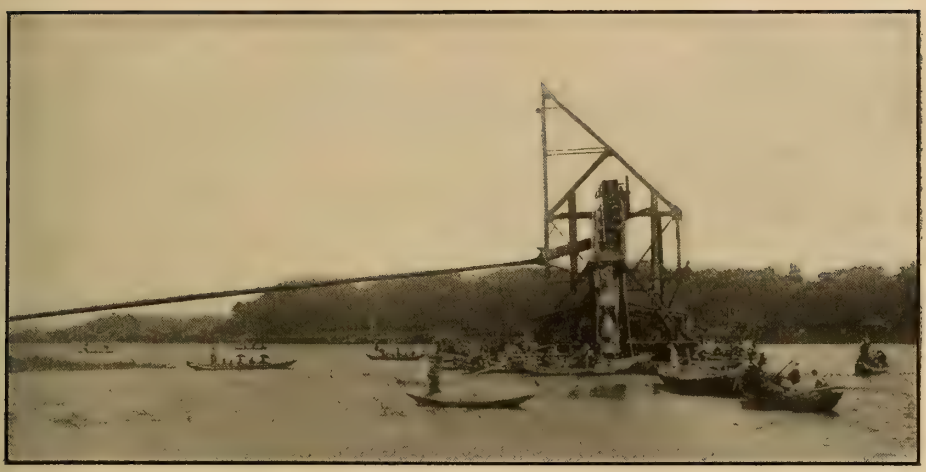
It occasionally occurs that the bed of a river passes over rock formations, which are usually effectual in preventing the deepening of the river except by means of blasting. When rocks had to be removed the old system was to drill holes about 2 inches in diameter, which were then filled with blasting powder. Care had to be taken in the arrangement and firing of these charges in order to prevent accidents. The system of Messrs. Lobnitz consists of using a heavy chisel weighing about 15 tons, which is lifted from 6 feet to 10 feet by a steam-driven winch and then allowed to fall on the rock at the bottom of the river by means of gravity. This is repeated until the rock has been pierced for a depth of about 3 inches, when the whole cutting gear, which is mounted on a raft, is moved 3 or 4 feet away and the operation repeated. Under ordinary conditions it is necessary to deliver about fifteen blows in order to pulverize one cubic yard of rock ready for dredging. It is, of course, necessary to thoroughly clean the sur-



A BUCYRUS DREDGE ON THE FOX RIVER IMPROVEMENT WORKS, SHOWING BELT CONVEYORS IN SERIES FOR DELIVERING SPOIL



DREDGING CHANNEL ON THE FOX RIVER, WISCONSIN; BUCYRUS DREDGE AND BELT CONVEYORS



LONG-CHUTE LOBNITZ BUCKET DREDGE

face of the rock by dredging before the rock breaker is used, as otherwise a large percentage of the force of the blow will be dissipated before the rock is touched. It is found that, owing to the partial pulverization of the rock by this process, it is easier to dredge than rock which has been blasted. The special feature of the cutter is the chisel point, which is made of chrome steel with a very hard centre. In shape the point is like a shell for a gun, and is so hardened that it keeps its shape even when at work, and when reduced to half its original size it still has its sharp point. A most ingenious method is employed for fixing this point into the cutter; the latter is heated and shrunk onto the point, and then an iron ring is shrunk around this to prevent any tendency towards burst-

LONG-CHUTE SUCTION DREDGE AND OVERHEAD PIPE LINE, USED FOR RECLAMATION PURPOSES. LOBNITZ & CO.

ing. Finally, a large screw prevents any possibility of twisting, by which the point might be lost after a series of blows. This system when first introduced was not entirely successful, owing to the fact that the cutters were too light for average service; but with the present 15-ton cutter the number of blows required is so much reduced that the system is much cheaper than blasting. Moreover, it has the great advantage that it can be used in close proximity to shipping. This rock breaker attracted a considerable amount of attention on its first appearance, and at the 1907 Engineering Conference of the Institution of Civil Engineers Mr. J. W. Sandeman, M. Inst. C. E., gave some particulars of rock-removal operations in the harbour of Blyth, Northumberland, from which the following results are abstracted:

In comparing the method of rock drilling and blasting with rock breaking by means of the Lobnitz cutter, these figures were obtained:

	Per Cub. Yd.
Cost of drilling and blasting rock	3s.
Cost of dredging the same	3s.-2.2d.
Total	6s.-2.2d.
Cost of breaking the rock by rock breaker	1s.-2.5d.
Cost of dredging the same	2s.-9.1d.
Total	3s.-11.6d.

A saving on 500,000 cubic yards of Blyth rock, which is the sandstone of the coal measures varying from friable stone containing fire clay, shale and coal to sandstone equal in hardness to basalt, equaled £54,166.

It will be seen from the above summary of the means available for dredging operations that a considerable degree of advance has been made in such apparatus since the days prior to the introduction of heavy machinery, when the "bag and spoon" dredger was used. The cost of operation and maintenance of dredging plant has been largely reduced, and it is, therefore, not too much to hope that, with the growing realization that internal freights for industrial products depend to some extent on the possession of an alternative means of slow-speed transport to the railways, these being reserved for quick delivery of light goods, thus avoiding congestion of goods traffic, some closer attention may be given to a general scheme of improving not only internal waterways, but the means of communication with ocean-going boats by means of both larger and smaller harbours. That this will involve a large initial expenditure is not to be gainsaid, inasmuch as in many cases years of neglect will have to be atoned for; but it should be pointed out, on the other hand, that the means of promoting efficiency and economy in operation are at the present day so largely in excess of former conditions that the possibility of reconstructing complete waterway systems is worthy of further consideration.

THE DEVELOPMENT OF THE AEROPLANE

By Henry Harrison Suplee

In concluding this study of the principles of the design of machines for mechanical flight the writer has endeavoured to gather together some of the data deduced from the dimensions of machines which have proved more or less successful in actual operation, and thus provide material for checking the computations based on theoretical considerations. He has also offered some suggestions concerning motors for flying machines, in the hope that future work along these lines may result in the development of special apparatus for this special service.—THE EDITOR.

WE have seen that one of the essential features in successful flight, not attained by the earlier experimenters, is that of maintenance of equilibrium.

Everyone knows how unstable a kite is, and how in most forms a tail of some sort is necessary, in addition to the tension upon the end, to prevent pitching and possible inversion.

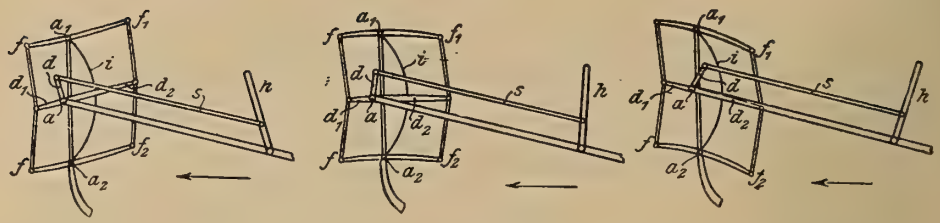
In the experiments made by Lilienthal and by the Wrights, in gliding, the absence of a motor removed any steadying action which such a force might give, while the fact that no form of tail or pendulum attachment was available rendered the question of balancing still more difficult. An idea of this element in the problem may be obtained, in part, by considering the behaviour of a monocycle coasting down hill without providing any control over its propulsion. In the case of a bicycle, the machine may tip to one side or the other, but is fairly stable fore-and-aft, so to speak. With a single wheel, however, the rider may fall forward or backward, or to either side, and this is practically the condition with a simple gliding plane.

When the planes or wings are made wide enough there is a certain degree of lateral stability provided, always assuming the air to be still, or, at least, free from eddies, but if the motion of the machine is not in a straight line, or if there occurs, for any reason, a tendency to tip over, some means of righting the apparatus must be provided.

So far as ordinary steering is concerned, this is naturally provided for by the use of vertical and horizontal rudders. For the maintenance of control over the lateral position of the machine some additional governing device was evidently necessary, and gliding experiments showed that this control might be effected either by using the ends of the main planes themselves or by providing auxiliary controlling planes, arranged as tips, in the case of a monoplane, or as auxiliary planes between the main planes, if a biplane; or by warping or bending the ends of the main planes themselves. This latter method is that used by the Wrights in the machines with which they have made public demonstrations. Examples of the other methods are seen in the Curtiss machine, with auxiliary balancing planes between the main supporting planes; and in the Bleriot monoplane with its movable wing tips. In this latter machine the auxiliary balancing planes are placed at the ends, both of the main supporting planes and the vertical steering rudder.

The early experiments of Lilienthal were made with a single set of planes, although his later trials, including the one in which he lost his life, involved the use of superposed planes, or rather curved surfaces.

Following out the suggestions of Mr. Octave Chanute, the Wrights made their gliding experiments with a



POSITIONS OF VERTICAL RUDDERS OF WRIGHT AEROPLANE FOR ASCENDING, DESCENDING, AND HORIZONTAL FLIGHT

h, Controlling lever; *s*, connecting rod; $f\,f_1$, upper plane; $f\,f_2$, lower plane; the connecting rod *s* acts on the bell-crank *d d*, and the difference in the lengths of the arms causes the reverse curvature of the planes in ascending and descending.

double-deck machine, and in the light of subsequent developments we may divide existing, operative aeroplanes into the two principal classes: monoplanes and biplanes.

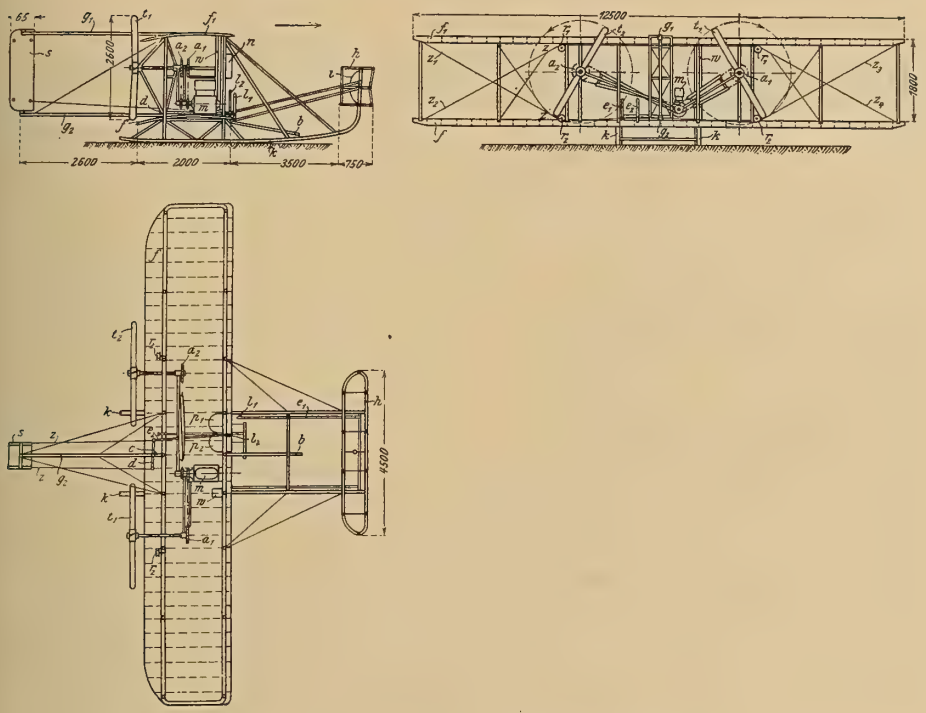
Taking up the Wright machine first, as the pioneer successful aeroplane, it may also be considered as the typical biplane. In general, it may be described as a pair of rectangular planes, about forty feet long and seven feet wide, the distance between the upper and lower planes being about six feet. Projecting in front are the horizontal rudders, a pair of surfaces about fifteen feet long by two and one-half feet wide, these being held by a framework at a distance of about twelve feet in from the main planes. These rudders are connected as shown in the illustrations, so that they may be tilted up or down, the connections being ingeniously arranged, so that when tipped downward the surface assumes a concave form on the upper sides, while this curvature is reversed when the rudders are tipped upward. This is accomplished by making the two ends of the double bell-crank lever *d*, d_1, d_2 of unequal length, so that the edges f_1 and f_2 are moved farther than the front edges *f*, *f*, when the hand lever *h* is moved backwards or forwards. Lateral steering is effected by a pair of vertical-plane rudders, carried about eight and one-half feet to the rear of the main planes, these vertical rudders being about six feet high and two feet deep.

The warping of the planes, to enable lateral equilibrium to be under the control of the operator, is effected by cords connected to the rear corners of both planes, these being passed over guide pulleys, as shown in the illustration, in such a manner as to bend one pair of corners up, and the other pair down, by the same movement of the lever.

The Wright machine is started by the impulse given by a falling weight in connection with a catapult device, although it has been repeatedly started from the ground under its own power, when the conditions have been favorable.

The two propellers, each about eight feet in diameter, are connected to a single engine by means of open and crossed chains, thus causing them to revolve at the same speed in opposite directions. Details of the machinery vary somewhat in the various Wright machines; the aeroplane shown at Reims was equipped with a motor of about thirty horsepower and weighed 937 pounds, including the operator.

The Bleriot machine may be taken as a typical monoplane, both on account of the attention which it has attracted because of the crossing of the Channel, and also because of the ingenious system of control. This machine has already been described by Mr. A. B. Rigby in the November issue of this magazine, but it may here be briefly mentioned also. Referring to the illustration, the main supporting plane is composed of two surfaces or wings *AA'*, of which the total spread is 8.60 meters (28.87 feet),



SIDE, REAR AND PLAN VIEWS OF THE WRIGHT AEROPLANE

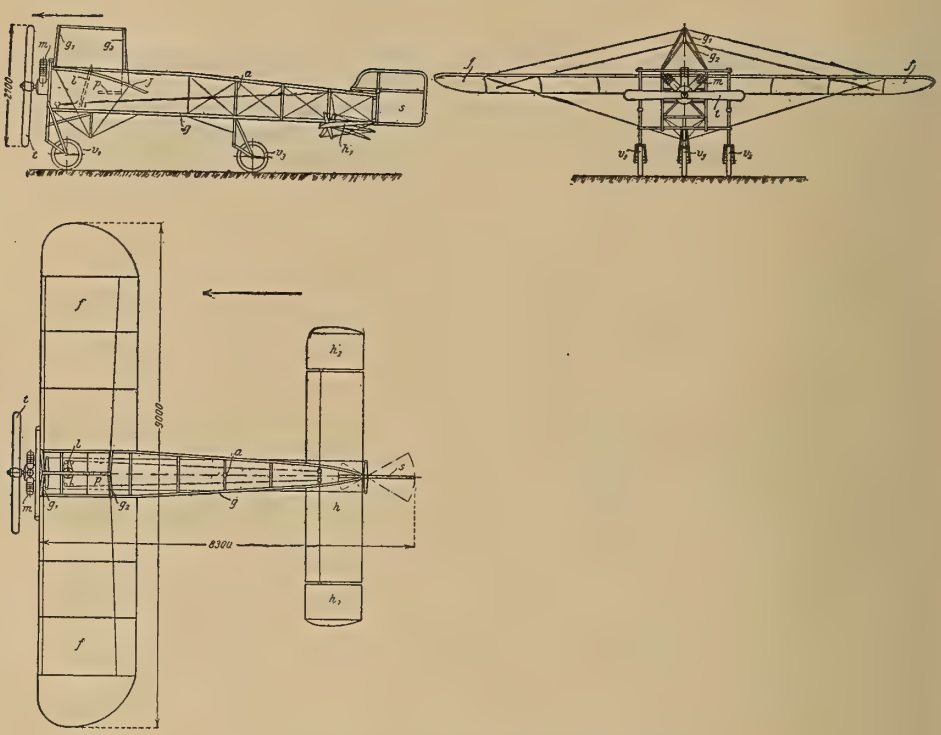
$f f_1$ Main supporting planes; k, landing runners; h, rudders for vertical steering; s, rudders for lateral steering; $l_1 l_2$, connections for operating the vertical and lateral rudders; z, cords to the lateral rudders; z_1 z_2 z_3 z_4, cords for warping the main planes; m, motor; a_1 a_2, propeller chains; t_1 t_2, propellers; b, connection to starting catapult; r_1 r_2, guide pulleys for warping cords.

and the general dimensions are given in the drawing. The single propeller is placed in front, and is driven by a three-cylinder Anzani motor of 25 horsepower. This motor consumes 0.4 litre of gasoline per horsepower hour, and the total weight of engine and accessories is 65 kilogrammes, or about 143.3 pounds; which 25 horsepower gives a weight of 5.7 pounds per horsepower. The motor is air-cooled, an arrangement which has been found satisfactory when the machine moves through the air, with a velocity of not less than 20 metres per second (about 45 miles per hour).

In connection with the crossing of the Channel in this monoplane, a comparison has been made of the progress of navigation through the air with that of navigation through the water. Thus the first trip of Fulton's *Clermont* was made in 1807, and the Channel was first crossed by a steamboat in 1816. It was not until 1838 that the *Sirius* and the *Great Western* crossed the Atlantic under steam, so that a period of twenty-two years elapsed between the two achievements. The Channel was crossed by an aeroplane on July 25, 1909, but in view of the rapid progress which has already been made in aviation during the past few years, it is altogether possible that in less than twenty-two years the Atlantic will be traversed by some form of aeroplane.

Probably the best comparative study of the present types of successful aeroplanes may be made by examining the various machines which were to be seen at the gathering recently held in France.

During the great aviation week



SIDE, FRONT AND PLAN OF THE BLERIOT MONOPLANE

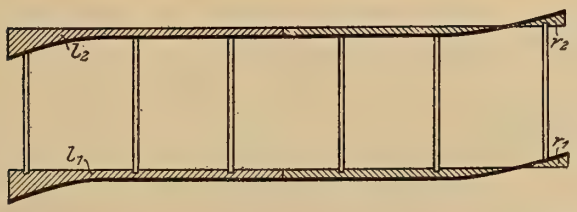
f f, Main supporting planes; *h h h*, vertical planes; *g g*, triangular bracing framework; m, motor; *s*, propeller; *l*, controlling lever for all movements; *v v*, supporting wheels.

held at Reims from August 22 to 29, 1909, nearly every practicable type of aeroplane was on trial. Thirty-eight machines were entered, although not all of these actually appeared. The gathering took place on the plain of Betheny, hitherto used as a military parade ground, and here a course of 10 kilometres (6.21 miles) was laid out, and here the men who had really made successful flights gathered to compete for prizes aggregating 150,000 francs.

Among the different types of machines were entered seven biplanes, those of Wright, Curtiss, Sanchis, Fernandez, Voisin, Farman and Breguet. The monoplane type was represented by five machines: the Antoinette, Bleriot (two machines), Esnault-Pelterie and Santos-Dumont. The Wright aeroplanes, seven in number, were all built in France, and did not differ materially from other examples of this now well-known type, with its two main rectangular sustaining planes having the warping feature which is characteristic of the Wright invention, and the two rudders in front for the vertical steering, and the two in the back for horizontal guiding. These machines were arranged to be started by a falling weight, and were provided with runners.

The Curtiss machine differed from the Wright aeroplane in having the main sustaining planes fixed, the lateral control being effected by movable wings between the main planes at each end. In this machine the rear rudder is of a cruciform shape. The Sanchis and Fernandex machines were practically the same as the Wright aeroplane.

The French biplanes differed from the American machines mainly in that



RESISTANCES DURING THE CURVED FLIGHT OF THE WRIGHT AEROPLANE

r_1 r_2, Turned upwards; l_1 l_2, turned downwards

there was added to the sustaining planes some form of tail, for the purpose of increasing the stability, a matter which, in the Wright machine, is dependent mainly upon the skill of the operator in balancing. The Voisin machine is one of the earliest and has remained practically unchanged. It is of the cellular type, the two main planes being connected by four vertical planes. The pressure upon the vertical partitions is supposed to aid in righting the machine when it is inclined in either direction. The tail is composed of two planes, between which is placed the rudder for lateral steering, while a single horizontal rudder in front serves for vertical steering.

The Farman machine has no vertical partitions in the main planes, but there are movable wings for the control of equilibrium. The vertical governor, placed well in front, has a wide range of movement, while the tail consists of two horizontal planes, between which the double rudder for lateral control is placed.

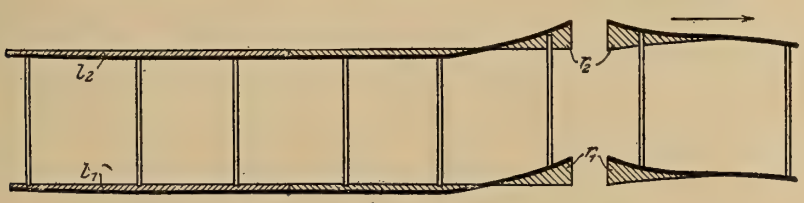
The Breguet aeroplane is a well-designed machine, and in the second example shown at Reims it gave the impression of excellent construction. The equilibrium was affected by warping the upper planes, while the tail included both the horizontal and vertical rudders.

The monoplanes included five Bleriot machines, of two different types, three Antoinettes and four Esnault-Pelteries.

The Bleriot machine of the so-called Calais-Dover type, similar to that in which the crossing of the Channel was made, is the smallest of any yet used, having 14 square metres of sustaining surface and weighing but 225 kilogrammes, or, with the operator, about 300 kilogrammes, so that the load is about 21 kilogrammes per square metre.

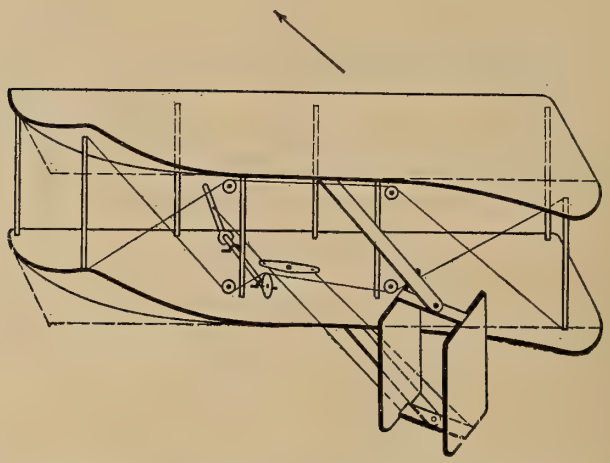
The Antoinette aeroplane, the type used by Hubert Latham in his attempts to cross the Channel, does not differ greatly from the Bleriot machine, although it is somewhat more graceful in its general appearance. There are two main wings, capable of warping or of using movable auxiliaries. It is provided with a tail for the purpose of adding stability, the total sustaining surface being 30 square metres, for a total weight of about 500 kilogrammes per square metre.

A study of these machines affords



SUPPORTING PLANES OF A BIPLANE WARPED ON ON SIDE ONLY

r_1 r_2, Right-hand aft edges turned upward; l_1 l_2, left-hand aft edges in their normal position, somewhat turned up



PERSPECTIVE VIEW SHOWING THE ARRANGEMENT OF WARPING PLANES AND STEERING RUDDERS IN THE WRIGHT AEROPLANE

some data of a thoroughly practical nature which may serve to guide future designers:

DATA CONCERNING AEROPLANES

BIPLANES

Name.	Area of Planes sq. ft.	Total Load lbs.	Load per sq. ft.	Power.
Wright	517	937	1.81	30
Curtiss	258	550	2.16	25
Voisin	484	1,270 / 1,600	2.57 / 3.30	30 / 54
Breguet	550	1,710	3.10	55

MONOPLANES

	Sq. Ft.	Lb.		
Antoinette	323	1,100	3.10	50
Bleriot	150	660	4.40	25
Esnault-Pelterie	214	1,000	4.45	35

An examination of the above facts, which represent the particulars of the principal machines at the Reims trials, shows that the monoplanes carry a much heavier load per square foot of supporting area than do the biplanes; this fact being accounted for by the fact that the monoplanes are usually operated at a much higher speed, and thus gain their increased supporting power in accordance with the laws discussed in the preceding article. This is well shown also in the double figures given for the Voisin biplane, the increase in power from 30 to 54 horsepower, enabling a higher speed to be maintained, and hence a greater proportional load to be sustained.

In view of what has already been shown regarding the excellent ideas of some of the early inventors, surprise has been expressed that the production of the successful aeroplane should have taken the length of time which elapsed from the experiments of Henson, in 1842, to the successful work of the Wrights, in the early years of the twentieth century. It has already been said that the real incentive to rapid development in aviation was the improvement in the internal-combustion motor, which reduced the weight per horsepower from the 132 pounds of the electric motor of Renard, in 1884, to the present weights of six to ten pounds.

This development, achieved for an altogether different purpose, in connection which the production of mechanically-propelled vehicles, came along just at the time during which Lilienthal, Pilcher, Maxim, Langley and the Wrights were conducting their experimental work in gliding, balancing and design, and it was the combination of the two which made the successful machine possible.

In the design of motors for flying machines, the mistake is sometimes made of aiming at too great lightness; that is, at lightness at the expense of reliability, strength or convenience. The points which have been found to need the most attention in connection

with the motors of automobiles are the ones which demand especial care in the construction of aeroplane motors.

Thus, reliability is essential above all things. The ability of an aeroplane to remain in the air is wholly dependent upon its forward motion, and while the machine is able, if properly handled, to glide to a safe landing when the motor is stopped, it is necessary that the place of landing shall be carefully chosen, otherwise great risks are incurred. The failure of Latham to cross the Channel was due to the stoppage of the motor of his machine, and although he was able to keep afloat until the escorting vessel reached him, such help might not have arrived in time. Bleriot, in his successful cross-Channel flight, was nearly an hour ahead of the *Escopette,* the torpedo destroyer which accompanied him, and had he met with disaster it is extremely improbable that help would have reached him in time. Even when the operator is able to choose his landing ground, he should have his motor under immediate control, so that, if necessary, he may accelerate his motion, and select the precise point at which the ground is reached. Thus it is evident that reliability is the prime essential of an aeroplane motor. Since interruptions sometimes occur in connection with the ignition, and as no opportunity for adjustment or repairs is possible, the best precaution against stoppages from defective ignition is found in the reduplication of parts. The probabilities of two independent igniters failing simultaneously is remote, while the stoppage of three is practically out of the question, unless the defect arises from some cause which wrecks the entire machine. The same is true with respect of carburetters, and thus the best plan for aeroplane motors is to provide several independent devices for the supply of gaseous fuel, the failure of all of which must be necessary before the motor shall stop.

The question of the carburetter is a most important one, since the operation of this portion of the motor is affected especially by the changed conditions which obtain in connection with travel through the air. The machine may be inclined in almost any direction, thus changing the level of the liquid fuel and affecting the whole operation of the apparatus. The presence of any particles of dirt or dust, which may impede or wholly check the flow of the gasoline through the small openings, cannot be entirely prevented, and thus a serious possibility of stoppage exists. It is desirable that the question of the carburetter for the aeroplane motor should be given especial attention, in the hope that a thoroughly reliable device may be perfected. In some motors the distrust of the carburetter is such that it has been abandoned, the liquid fuel being injected directly into the cylinders, much in the same manner as in the case of the Diesel motor; a plan which works all right after the cylinder has become fully warmed up.

In some motors the propeller is connected directly to the engine shaft, but in most cases the rotative speed is rather too high to render this mode advisable, and there is some form of reduction gearing employed. In the Wright machine, in which two propellers are used, these revolving in opposite directions, the propellers are driven from a single motor; chain transmission being used to deliver the motion from the engine, with open and crossed chains, to secure the desired direction of rotation. In some cases the propeller is attached to the camshaft of the engine, this being geared to run at one-half the speed of the main shaft, to secure the proper valve movement, and thus giving a satisfactory propeller speed with an engine at double the rotative velocity.

It is possible that with future developments some machine of the gas-turbine type may be found available for aeroplane propulsion. Such a motor would necessarily have a high rotative velocity, probably from 10,000 to 20,000 revolutions per minute, necessitating immediate speed reduction by gearing. This is no greater demand

than has already been successfully met by the De Laval steam turbine, and hence is easily attainable with the gas turbine.

In designing a reciprocating engine for minimum weight, the fundamental principle is doubtless that enunciated by M. Esnault-Pelterie, that of equalizing as much as possible the stresses, and thus enabling the parts to be made of such dimensions as may be required to the average strains. Internal-combustion motors are primarily operated with implses of very unequal effect, the explosion at the beginning of the stroke being powerful, causing a great initial pressure, falling off rapidly as the stroke progresses. The working parts of the motor must be strong enough to stand these high initial forces, and it is these forces which must be used in computing the dimensions, and hence the weight of the various members of the engine. When several cylinders are used a corresponding distribution of forces may be made, especially if the cylinders are disposed about the crankshaft in such a manner that the turning efforts are distributed throughout the framing and on the shaft. A number of moderate stresses are thus substituted for fewer impulses of greater magnitude, and although the total power developed is the same, none of the members is stressed so severely as is the case in engines of a small number of cylinders arranged so as to repeat the impulses in the same direction. By following out this idea, it has been found practicable to reduce the amount of strain upon the members of a motor, and thus permit a material diminution in the weight of the whole machine. This principle would appear to be carried to its limit in the case of the gas turbine, in which the turning effort is continuous, and the stresses correspond at all times to the average.

In considering the question of the weight to be allowed for the motive power of an aeroplane, due attention should be given to the relative importance of the weight of the machine itself and the weight of the fuel by which it is fed. If long-distance flights are to be made, the weight of fuel will become a more important element than the weight of the engine itself. Under such circumstances it is better to permit a slightly greater weight for the engine, if thereby a greater economy in fuel consumption can be effected. Although fuel economy is desirable as a matter of reduction in operative cost, this consideration may be considered secondary in comparison with the extension of flying radius thereby effected, a matter which has not received the attention which it deserves.

The question of framework and fabric for the construction of the main structure of an aeroplane still remains to be definitely settled. The framework must be reliable, since any failure means loss of equilibrium and almost certain fall and destruction. The machine must be mainly constructed on what has been termed the "fiddle" principle, the members being connected by light rods and wires, capable of adjustment, so far as tension is concerned, and made of material of the most reliable nature possible. As the development of the automobile has resulted in the production of special alloy steels and other materials, so the progress of aeroplane design will doubtless bring out special structural materials for the special service demanded. The covering of the planes requires a material which shall be at the same time light, strong, impervious and durable. This question is one for the manufacturers of india-rubber products to solve, and they will doubtless meet the requirements as they arise.

We thus have an industry which is in its infancy, but which seems destined to follow along the lines which have already appeared in the development of the bicycle and the automobile. The first demand for the aeroplane may be expected to come from the sporting element of society; the question of cost thus being subordinated to those of speed, manageability and control by a single individual.

Such a demand will undoubtedly permit improvements to be made which might otherwise be much longer in appearing. In the meantime there will appear a moderate demand for machines for practical service, a demand which may gradually surpass the requirements for racing or exhibition machines, and which will call for apparatus of less showy and more useful character. Side by side with these elements in the development will undoubtedly appear a factor which failed to affect appreciably the design of the automobile, the demand for a flying machine for military service.

It is altogether possible that the military aeroplane may become more effective in the development of the machine than any other type. The impossibility of making the automobile a cross-country machine limited its value for military purposes, so that it created but little attention in that department of effort. The open highway of the air causes the flying machine of any successful type to enter almost immediately the arena of military operations. The dirigible balloon appeared to offer the first attractions to the soldier, but experience has demonstrated the serious limitations of these bulky and unwieldly machines.

The fact that the aeroplane has already made flights of more than a hundred miles, that it has been employed successfully to overcome the isolation of the British Isles from the Continent, and that it can make flights at night in such a manner as to be extremely difficult to attack, renders it almost immediately a possibility in warfare. It is already available for scouting and reconnaissance. It may soon be effective for offensive attack in connection with the use of high explosives, and the fact that nearly every great power is seriously considering its acquirement and application marks a peculiar phase of development which may well warrant attention.

These considerations may be taken into account in studying the problems of this new department of engineering industry. The air is open as a field for conquest; the way has been prepared; the methods have been briefly indicated. What the results will be depends almost wholly upon the efforts of the engineer, and it is impossible to predict the scope of an art just entered upon its practical existence.

Current Topics

THE flying machine has, to use a slang term, come to stay. It is a success that is probably quite as safe as the motor car, and the greatest anticipated difficulty—of coming to earth—seems to have been solved in a very easy manner. Indeed, in all the press talk, nobody seems to have been led by any mischance to give us a few words on coming down.

Now to fly, it is simply necessary to exert an upward lifting force greater than the downward pull of gravity. The question is how to do this. It has been solved, as we all may see by driving a fairly large plane, or nearly plane, surface through the air at such a velocity as to cause the air to exert a pressure on the lower side of the plane equal to the weight to be sustained, or a little in excess of that weight. If a plane surface with a tilt on the leading edge of, say, 8 degrees upward is driven along horizontally there will be created such upward pressure by the wedging action of the moving surface, and the plane will try to rise along a line inclined 8 degrees. Eight degrees represents a rise of 1 in 7, so that at a speed of 42 feet per second such a surface would rise 6 feet in that time apart from what gravity did to pull it down. Gravity should, nominally, pull it down 16 feet in that time, but the broad expanse of wing appears to prevent the air from escaping laterally at sufficient speed to allow the plane to fall and the net result is that the plane is sustained.

It would appear, therefore, that large machines should fly more easily than small ones, and that slower speeds should be possible with them, and it appears to us that prizes for the slowest flights should be offered rather than for the most rapid flight, for it is in slow flight that the best value of a machine should be found. What that value will be no one at present can say, but it seems certain that before long there will be hundreds of people who will fly. A monoplane is the sort of thing that an amateur could make for himself out of a few bamboos, an old camping tent, or some old tracing linen. He would buy his engine and fly forthwith.

IN an article appearing upon another page in this issue, Mr. Smallwood calls attention to the extent to which the apparently dissimilar professions of engineering and

art have sometimes been associated. We may be permitted to add a number of names to his list of artist engineers, and to emphasize the fact that the "scientific use of the imagination" is a most important element in technical success.

The older architects and engineers were nearly all artists. Probably the most eminent example of this combination is found in the career of Leonardo da Vinci, of whom it is difficult to say whether he was greater as an engineer or as an architect. In like manner Michael Angelo may well be called an engineer when we consider the skill with which he designed the structural features of the buildings with which he was entrusted. Still earlier we find the mediæval cathedral builders, the beauty of whose work entitles them to be considered as artists of the highest class, were also engineers of great ability, employing the methods of the catenary and of the equlibrium of forces in proportioning arches, flying buttresses, piers and foundations.

Even when the artistic and imaginative faculty is not actually employed by the engineer it is frequently associated with his occupations and leisure, and many successful engineers have been noted for their taste and judgment in the cultivation and patronage of the fine arts and of literary works of the imagination. It is well to remember that such elements in the engineering temperament are the frequent accompaniments of success, and that the best engineer is not necessarily the man whose work is uninfluenced by his imagination.

WHILE zinc is cheap it is questionable whether it may not be replaced by copper for roofing purposes where atmospheric conditions are bad. Experiments at a Berlin testing laboratory are said to have shown that in an atmosphere loaded with sulphuric acid and steam, zinc lost eleven times as much as copper. But copper is not eleven times the price of zinc as a rule, and it may be employed in much thinner sheets. Thin zinc on roofs five miles from Charing Cross has been known to become badly perforated in twenty to twenty-five years. This is the weakness of zinc; it rots in little spots, which let in water freely and are not easy to find. Copper appears to waste much more evenly, but very slowly. Lead appears to have an indefinite life, and it is often a cheap metal per weight, but it weighs much per unit of area. If used as thin as zinc is used by the cheap builder, it would cost little more, and its life would be very much greater. Zinc is quite unsuitable for city roofing owing to its easy solubility by acid rain.

HOW much finish ought to be put upon a machine? Superficially speaking, so long as the working parts of a machine are truly and properly machined there is no reason for any finish. And it may be argued that finish may do positive harm, as when the skin is turned off a nicely forged shaft. Paint is a good enough finish for plenty of things once got up bright. Well, so it may be in theory, but there is something in finish after all that can never be got to stick to a crude, rough, unfinished article. Human nature enters into the question. An outwardly finished engine will receive better care than one that has been left rough. And this attention will cumulate until ultimately two machines, which start out with equally good working surfaces, will have differentiated themselves until their working parts are as different as their outward appearance. A highly intelligent, well-paid man might perhaps keep the ugly engine as well as the cheap man kept the finished engine. But finish is put on so that the ordinary and cheap man may be induced to good work. Finish properly applied will pay for itself, and especially in sheltered machinery is it really easier to keep clean a bright than a dull surface. Hence the polishing of cover plates on textile machinery. They might be painted, but would never

look or be so clean or bright as buffing will make them.

WE have often wondered when reading discussions on the merits and demerits of compound locomotives why locomotive men have struggled so much to find a good system of compounding, and have so thoroughly neglected superheating. For by superheating steam we place the simple single-expansion engine a very long way towards being as economical of steam as the compound engine, and we enable all the complication of compounding to be dispensed with. The application of superheating to the locomotive presents a certain difficulty. The problem is not so difficult if tackled with a new engine or when retubing a boiler. We refer of course to the superheaters of the type which can be readily exchanged for repair or inspection. With interchangeable apparatus so simply connected, there should not be much difficulty in giving superheat a fair trial.

Mr. Demoulin says that simple locomotives with superheated steam at 330 degrees to 350 degrees centigrade are as economical as compound locomotives using saturated steam at 60 pounds higher pressure, while they will also haul 20 per cent. more load. And he would put superheaters to compound locomotives also. But the simple locomotive is so very much handier in working that the double complication is perhaps scarcely likely to be a favourite.

COMPLAINT is made of the business dishonesty of the Japanese. This is explained to be due to the fact that the best class in Japan, the Samurai, had nothing to do with trade. The Japanese Government, which is of the Samurai class, is careful and honourable in its dealings, and has just issued a circular through the Minister of Agriculture and Commerce admonishing various Chambers of Commerce to mend their members' ways and to conduct business so as to gain confidence. Traders are desired not to transgress the laws of commercial "Bushido," but to strive after prosperity by "honourable" means.

Those who know Japan and the people say that the fraudulent dealing is simply a matter of passive rather than active fraud. The classes who swindle are unmoral rather than immoral. Let them once perceive what ought to be done, and it may be they will copy the very best traditions of commerce and be as keen in honesty as they have been in shipbuilding and other arts. Meantime, perhaps, it would be just as well if our own commercial men would see to it that they are not found too far behind the Japanese.

WRITING on power-station design in a contemporary, an engineer points the folly of placing pumps and other accessory machinery in the cellar beneath the heavy, solid floor of the engine room and, therefore, out of the command of the engine-room traveler. He suggests the use of open floors, railed round so that the heavier accessories can be lifted directly by the main traveler. There must, of course, be certain floor areas sufficiently strong to carry a heavy piston or a cylinder cover; but it is by no means out of the way to design a floor so that it can be removed in sections and such parts as named above put down the opening and rested on the solid floor of the cellar. An architect naturally tends to make all cellars dark, for cellars have been dark from time immemorial; but engineers should desire not to be trammeled by such old ideas and should regard basements and cellars as places to be kept as light as possible, and floors merely as so many gangways whereby to reach to the parts of an engine. And is it not a simple matter to design a steel-framed door and fill or cover portions of it with mosaic-filled plates? Indeed, why not let the floor be the floor and regard all other platforms, including the engine-room "floor," merely as means of access

to working parts? As it is, a big engine room consists of two heavy concrete floors, from the lower of which rise concrete piers on which the engines are stood. Why be ashamed to show these piers to the fullest light? Why conceal them by useless second floors at vast expense? It all reminds one of the Scotch railway engineer who declared it impossible to build a railway in Holland, for there was not the where to run the tunnels, and no early railway but had its tunnel! And so the modern engine must recall by its construction those cavernous depths of the old beam engine, wherein were vast blocks of ashlar masonry, great tanks of cast iron, in which stood condensers and huge, coughing air pumps and lunging delivery and foot valves. All was a dark, splashy and mysterious cavern, into which a long crank and a connecting-rod end would dip, through a slot of light, occasionally, and wheels rumbled in the darksome corners.

The influence of precedent is still strong in all departments of work, and the engineering profession is governed in many things by the relics of obsolete practice much in the same manner as in the professions of law and medicine.

JAMES NASMYTH

A RETROSPECT

IN these days of mechanical and technical progress it is sometimes interesting and profitable to turn back to the work of the pioneers in the engineering profession and to look into the relations of the work of the men who have gone and the efforts of their followers. In so doing some rather unexpected points may be brought out.

There has just been held, in the city of New York, the centenary of the origin of practical steam navigation, as exemplified in the work of Robert Fulton. Although some attempt has been made to grasp the fact that the whole development of steam navigation has thus been included within the brief compass of one hundred years, yet it is realized by but few that the entire period of the use of steam power for all purposes is but forty years longer, while it is less than seventy-five years since steam railways have been in operation.

As a matter of fact, there has intervened the span of but a single life between the present time and the invention of the steam engine. The first patent granted to James Watt bore the date 1769. In the year 1817, when Watt was in his eighty-second year, there was held a gathering in the city of Edinburgh, at which the host was the Earl of Buchan, and at which, amongst other notable guests, there were present James Watt, Sir Walter Scott, Mr. Francis Jeffrey, the editor of the "Edinburgh Review," and Sir James Hall, the president of the Royal Society. To this notable assemblage there was brought, by Mr. Alexander Nasmyth, his little son James, then not yet ten years of age, that he might see and listen to these great men and remember them in after years.

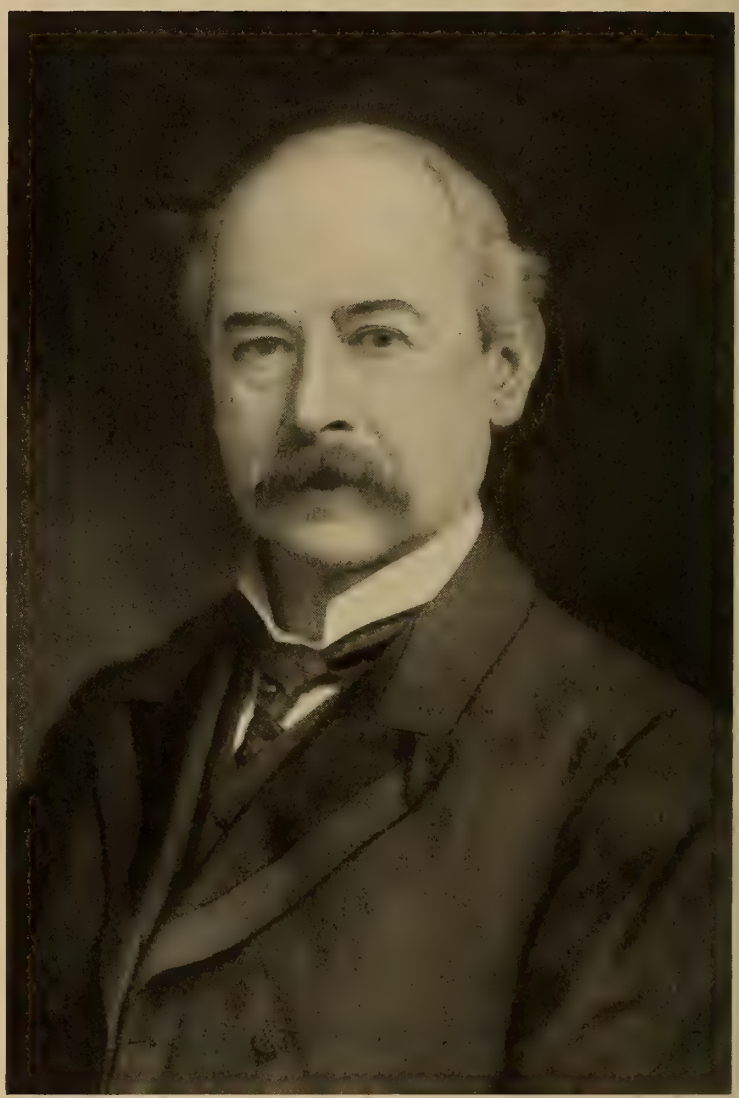
In the year 1889 the present writer had the privilege of visiting, at his beautiful home at Penshurst, in Kent, Mr. James Nasmyth, then in his eighty-second year, and of hearing him narrate the story of the meeting, seventy-two years before, with the great inventor of the steam engine.

Thus the life span of the inventor of the steam hammer, of the shaping machine, of the reversing rolling-mill, of the gate valve, of the flexible shaft, and of a host of minor devices, became also a living link, joining the beginning of steam engineering with the present. Upon that occasion the venerable engineer presented to the writer the photograph which is reproduced as the frontispiece to this magazine.

In 1830 Mr. Nasmyth visited Manchester and there saw the "Rocket," which, the year before, had demonstrated the possibilities of steam locomotion; and witnessed George Stephenson with his hand upon the throttle and saw Robert Stephenson acting as stoker, and thus transmitted the story of the commencement of steam railways.

The science of engineering has progressed with accelerating speed since those days, but the Victorian period may truthfully be said to have been made famous by its engineers, as well as by its literary men. Maudslay, Fairbairn, Whitworth, Napier, the Brunels, Bessemer—these and their companions were the associates amongst whom Nasmyth did his work and with whom he laid the foundations of modern engineering. He outlived them all, and passed the traditions of that brilliant period on to those who, following, have entered upon the heritage of great deeds, and who have borne aloft the worthy standard of the profession whose end and aim is "the direction of the great sources of power in Nature to the use and convenience of man."

H. H. S.



Photograph by Elliott & Fry, London

SILVANUS P. THOMPSON, D. Sc., F. R. S., Etc.

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CASSIER'S MAGAZINE

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THE NATURAL RESOURCES OF THE PHILIPPINE ISLANDS

By Monroe Woolley

THE growing dependence of the United States upon the tropical and sub-tropical world for food and manufacturers' materials will in time cause a more kindly light to be thrown toward her colonial possessions. The appalling sum of $600,000,000 worth of tropical products come into the United States annually, mostly from countries from which there is no compensating trade, as against $200,000,000 worth in 1875 and about $300,000,000 worth in 1895, thus showing a substantial increase as time goes on.

Now, as long as a nation possesses a vast tropical empire second to none in bounteous production in the world, the utter folly of buying abroad may be quite obvious. Nevertheless, when the sum of $20,000,000 was paid for the Philippines many persons looked upon the deal simply from the viewpoint of the real estate agent—there was received so many square miles of soil in the form of mountains, hills, forest lands and rolling plains, and no more, totalling nearly 127,000 square miles of landed area, located away out in the Pacific, from twenty to thirty days from San Francisco, according to the speed of the ship, from three to four days from Japan, five days from Australia, and a trifle over a day from the China coast. Altogether, there were some 3,000 islands, some of which should properly be dignified with the title and some of which should not.

But what the acquisition of the archipelago brought in natural wealth and latent resource few people realized. Perhaps people at home were too busy to stop to find out. Yet with the stewardship of this insular empire, with increased activity at home, an ever-growing demand for tropical products, the United States was confronted with not one but several entirely new conditions. Congress has just realized this important fact by enacting legislation which brings the island products in duty free, the same as similar products have been coming from Porto Rico and Hawaii. This new tariff law will be the main force for opening the door leading to a wonderful era of development and industrial activity in the Philippines.

Before going into an exhaustive and detailed account of the vast resources of these fertile island possessions, which raise bananas, pineapples and oranges in one quarter and Irish potatoes, strawberries and pine trees in another, it may be well to enter into some little description of the land about which much has been written and said of late, but which is,

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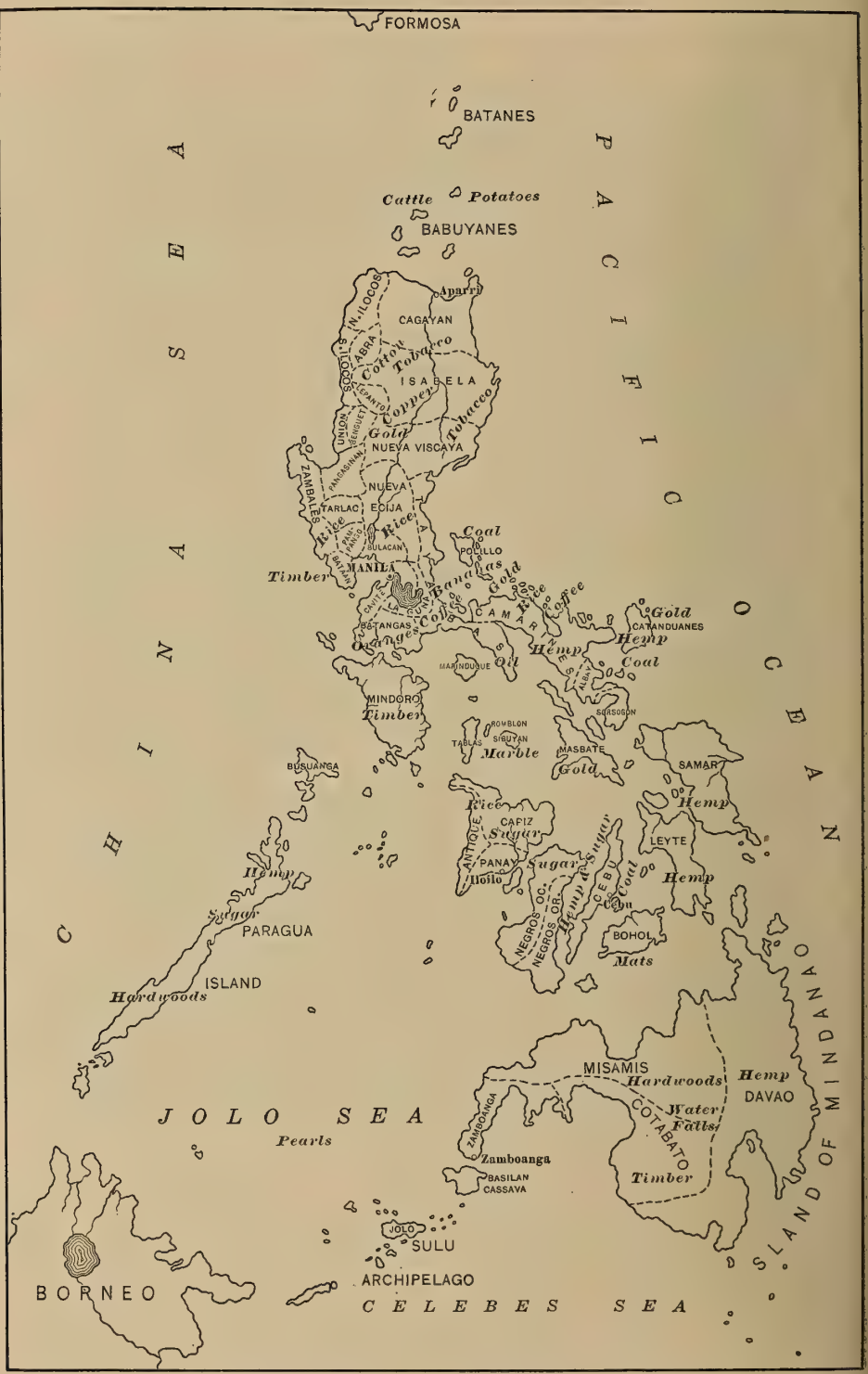


MAP OF THE PHILIPPINE ISLANDS, SHOWING PRODUCTS

nevertheless, in many respects misunderstood.

It is the boast of the Manila Merchants' Association in their "boost" literature that the association tells no lies, because the Philippines will stand the truth—a fact fittingly said.

Luzon, on which Manila is located, and Mindanao, the domicile of the Mohammedan Moro, to the southward, are the two largest islands of the group, either of them being larger than Cuba. Samar, a hemp-producing land, famous for its wild state and numerous rivers, ranks third in size. Leyte, its sister-isle, also a hemp district, is a large island close by. The Visayan group of islands, composed mainly of Negros, Cebu and Panay, form the sugar belt, and have an aggregate area of about 25,000 square miles. Mindoro, meaning in Spanish "mine of gold," is, perhaps, because of its unexplored regions, just now the most interesting island, from many standpoints, of the entire group. It has but few towns and a sparse population. The towns are all scattered along the coast, and it is claimed that not more than half a dozen white men have ever crossed the summit of its range of mountains or invaded the rich interior, which abounds in big game and many other interesting things.

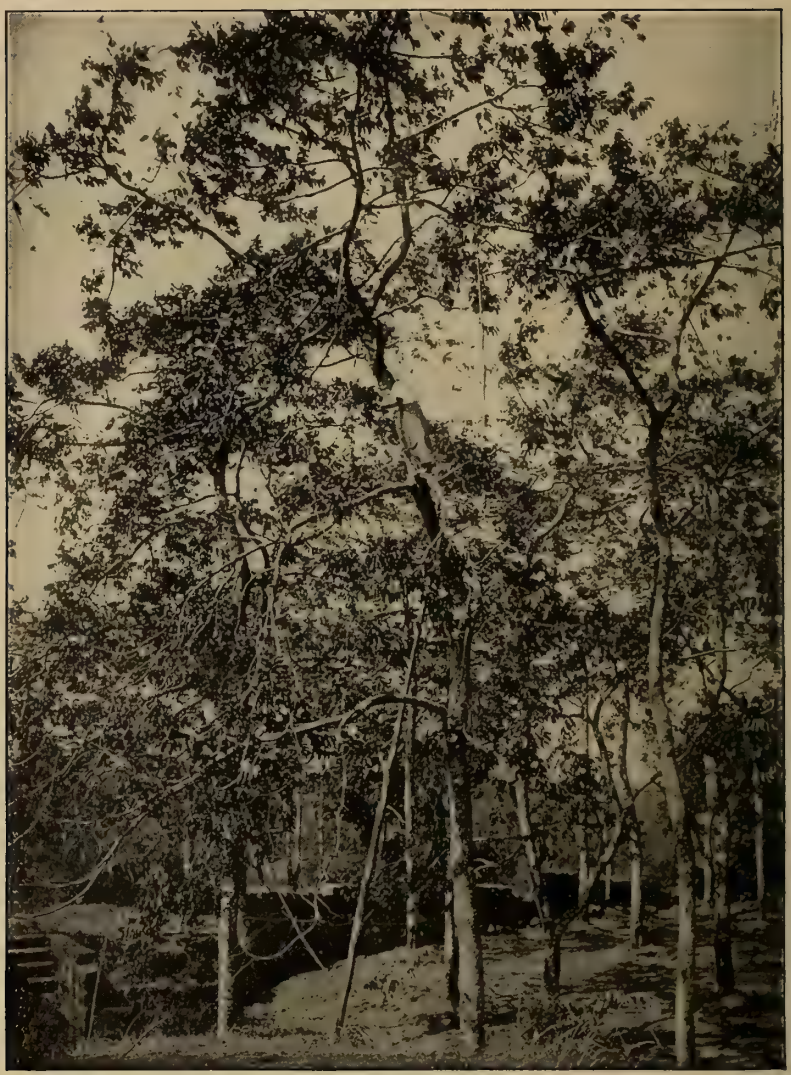
Of all the remaining bodies of land which stick their peaks up out of the China Sea in that locality none, save Masbate and Bohol, exceeds 1,000 square miles in area.

Bohol is the abode of a famous lot of fancy mat makers, the work of whom is equal in many respects to the Indian weaves of America.

Masbate is famous for her broad grazing fields, her wild horses and her gold mines.

The islands forming the Sulu archipelago, a part of the Philippine group, are small in size. They have

A PROVINCIAL CHURCH AND CONVENT



GATHERING THE BLOSSOMS OF THE YLANG-YLANG FOR THE PERFUME MARKET

been little exploited owing to the treacherous class of Moros, a race distinct from the Filipino, who live there. These islands possess about the same natural resources as Mindanao, located across the Jolo strait.

The natural wealth and undeveloped resources of the entire Philippine archipelago include a large variety of minerals, some comprehensive idea of which may be obtained from the following table, showing what is to be found in the islands:

Luzon—Coal, gold, lead, copper, iron, sulphur, marble, kaolin, asbestos and oil.

Catanduanes—Gold and coal.

Marinduque—Lead and silver.

Mindoro—Gold, coal and copper.

Semirara, Cacraray, Batan and Rappu-Rappu (all small islands)—Coal.

Masbate—Gold and copper.

Romblon—Marble.

Samar—Gold and coal.

Sibuyan—Gold.

Panay—Coal, oil, gas, gold, copper, iron and mercury.
Cebu—Coal, oil and mercury.
Biliran—Sulphur.
Negros—Coal, oil, gas, gold, lead, silver and iron.
Bohol—Coal.
Mindanao—Gold, coal, copper and platinum.
Panaon—Gold.
Sulu archipelago—Pearls.

MINING AND MINERALS

The extent of the mineral wealth of the Philippines is comparatively unknown. The varieties of ores are extensive, as indicated above, and the veins and ore deposit abundant. Just now coal and oil are occupying the attention of the government, while gold is attracting the private individual. The government for some years has been at an enormous annual expense in coaling, in Japan, the trans-Pacific transports, war vessels and inter-island fleets pertaining to the Philippine service. Recently, however, the rich coal fields in Batan, Rappu-Rappu and Cararay islands, in the Gulf of Albay, have been placed in operation. Lately President Taft ordered that Mango and Nagtagan islands be added to the government reservation composed of Batan and adjacent islands. These islands, all situated closely together, though small, are nevertheless rich in a very fine grade of coal, the amount of which, it is known, will supply all needs for many years to come.

Batan Island is the largest of the group comprising the government coal reserves. Half of the island is owned by a private company, which staked out its claim some time before the remaining half was set aside as a government reservation. This company is now working its holdings at a good profit, disposing of its product to coastwise steamship lines.

The island of Polillo, north of Batan and off the east coast of northern Luzon, which is by far larger than all the islands of the government coal fields combined, is said to possess coal beds the extent and quality of which are little known except to certain individuals who are

THE OLD HOTEL ORIENTE, THE WALDORF-ASTORIA OF MANILA, NOW THE CONSTABULARY HEADQUARTERS

QUARTERS OF THE MILITARY AID TO THE GOVERNOR-GENERAL AT MALACAUAN PALACE

supposed to hold claims there. Polillo, perhaps, has the richest veins in the entire archipelago.

Cebu has one or two mines which produce small quantities for local consumption; but, so far as known, none of the other fields is in operation, and none of those being worked, except the government mines, has anything like adequate or proper equipment for profitable operation.

Undoubtedly the richest gold holdings in the islands are those at Paracale, in the northern part of Ambos Camarines province. These holdings were formerly worked to some extent by Spanish and British companies, but they had been abandoned for some time when Americans became interested in them. Big strikes were recently made, and new companies have been forming thick and fast. One of these is the Paracale Extension Dredging Company, capitalized at $225,000, which is perfecting plans for the construction and operation of two new modern dredges. The ground of the company has been thoroughly bored and tested, the tests showing an average of 37½ cents per cubic yard. Besides the free gold, the ground carries a large amount of rich sugar quartz, and experts who have examined the property agree that it is very rich. Ore samples running $147.60 to the ton reached Manila not long ago from San Mauricio mine, in the Paracale district. These samples contain gold, silver, copper, lead and zinc. The assay made at the mine was borne out by the government assayists. This ore was taken from a 3-foot vein and contained $112.03 in gold, 26.54 ounces of silver, one-half of one per cent. of copper, 18.24 per cent. of lead and 2.58 per cent. of zinc.

In one day recently the dredge now at work at Paracale took out 25 ounces of gold, and before long there will be twelve dredges at work in these mines. Considerable development work is being done on quartz claims, several good tunnels having been opened recently.

American prospectors commenced operations on Masbate Island for gold nearly ten years ago, and, after much discouragement, the mines are now beginning to pay; but not until large sums were expended for costly machinery. "Masbate is to be the big lode mining country of the Philippines," says a Philippine pioneer. "Other parts of the islands may have greater placer workings, but for the

lode work alone Masbate will soon stand supreme." The Syndicate Company owning the Nancy lode has exposed for a distance of more than 200 feet a vein of ore nearly 60 feet wide and running over $5 to the ton.

The mines of Benguet province, near the summer capital of Baguio, have been paying property for some time. One of the prospectors recently sold his holdings in the Headwaters Mining Company to a Hongkong syndicate for $20,000. The Benguet Mining Company recently shipped to Manila a bar of gold weighing 233 ounces and valued at over $4,000. This bar, with another 82-ounce bar shipped earlier, represents the yield for free milling for one month. In addition to this, the company has about 10 tons of concentrates, assaying $100 per ton.

Dinean ridge, south of Paracale, is a network of veins; one vein in particular is believed to be the most valuable deposit in the islands. Mount Tinga, in the vicinity, has a rich lead mine which the government's experts claim ought to be worked. Natives have worked all over the Paracale district, sinking pits and shafts close together along the outcrop. Thousands of these openings have been found, ranging from five to one hundred feet in depth. The ore is free gold, galena and zinc blende in a calcareous shale, and occurs in rich stringers of calcite and of quartz. The method of treatment is outlined as follows: Rock crusher, ore bin, Huntington mill, amalgamation plates and concentrating tables.

The veins of the Mambulao district are, for the most part, contact deposits, between shales, gneiss, granites, schists and diorites. They are usually well marked, of good width, and carry excellent values. It is believed that this belt of mineralization extends across the island to Ragay gulf, where veins are found in similar character and strike.

NATIVE HARDWOODS

There lies ahead of the hardwood and furniture industries of the Philippines a splendid future. The islands possess the most beautiful woods in the world, and they are reaching their development just at a time when the world is looking for hardwoods. The timber is not located in thick "stands," but is well scattered, cover-

MILLION-DOLLAR ICE PLANT IN MANILA, ONE OF THE LARGEST PLANTS IN THE WORLD

ing, it has been estimated, an area aggregating 40,000,000 acres. Of this great amount less than 1 per cent. is under private ownership. Most of these woods, which have no equal in richness of colour, durability, brilliance of polish and size of timbers, are difficult to transport by water. Their texture is so close and their specific gravity so great that they quickly sink. Their weight averages about 75 pounds to the cubic foot; height, from 50 to 100 feet, the natural annual growth being estimated by the insular government at one billion four hundred million cubic feet, nearly all of which is now going to waste. In 1904 the Bureau of Forestry had record of some 396 different species; now the list has increased to 665, the species being well mixed.

Molave and lauan are, perhaps, the commonest commercial woods in the islands. From them the roughest construction work, including housebuilding, is carried out. Molave is more nearly like white oak than anything else. There is scarcely a home which is not supported by big molave posts, some of which have been in place for centuries and are still sound. Red narra, a beautiful rose-colored hardwood, is the finest Philippine mahogany. It can be put into the mill at $10 per 1,000 feet, while it sells in the islands for from $150 to $175.

A TENT SAWMILL IN THE EARLY DAYS OF AMERICAN OCCUPATION

The Filipino has never understood or been equal to the task of getting out these heavy timbers. With nothing save the strength of the caraboa and the exertion of brute strength on the part of woodsmen, the process has been slow, expensive and tedious. There are but eight steam sawmills in Manila, only three of which have modern machinery. The majority of the natives saw their lumber by hand, taking a day to get out two or three boards.

Three or four American firms now hold timber concessions, and it remained for a Yankee to establish the

first furniture factory the islands have ever known. Mindoro is extremely rich in hardwoods, and the natives there have been destroying the growth for agricultural purposes. On the mountain ranges are said to be many solid stands of pine. The government has estimated that the island contains 814,000 acres of solid commercial forest, containing at least 5,755,300,000 feet, board measure, of merchantable timber. In addition, there are about 262,000 acres that have scattered clearings and a non-commercial forest which will yield 400,000,000 feet, board measure. The principal timber species cut in Mindoro are guijo, narra, molave, calantas, ipil, dungon, apitong, lauan, malugay, amugius and aclengparang.

It is the object of Major George P. Ahern, director of the Bureau of Forestry, to increase the governmental income from the forest lands from $50,000, now received, into millions. To do this many concessions will be granted. Communal forest privileges are granted to any town that asks for them.

The approximate number of acres of available public forest lands in the leading countries is as follows:

Countries	Acres
Russia (Europe and Asia)	925,000,000
British possessions of Canada and India	440,000,000
United States	160,000,000
Japan	58,000,000
Sweden	50,000,000
Philippine Islands	40,000,000
Germany	35,000,000
Austria	24,000,000
France	23,500,000
Hungary	23,000,000
Norway	20,000,000
Spain	12,000,000

A NATIVE TOBACCO PLANTATION ON LUZON

To appreciate the above figures thoroughly, one should keep in mind the comparative size of the different countries named. It should also be remembered that the timber of the Philippines is nearly all of the most valuable hardwoods, while much of that of the other countries is largely made up of soft woods. All of the Philippine woods have great tensile strength, and nearly all of them take on brilliant polishes. Some of the timbers are so hard that tools are frequently broken in working them, and a blow from an axe will scarcely make an impression on certain kinds. Cog wheels, with thin and narrow

SANTA CRUZ BRIDGE, BUILT BY AMERICANS OVER THE RIO PASIG

teeth, can be made of some of the species. There are two kinds of narra, one a golden straw yellow and the other a carnation red, both being extremely valuable for furniture and cabinet work. Philippine ebony brings a very high price in China and Europe. Tindalo is highly esteemed in China, where it is said to be sold for its weight in silver and is valued as such. There are about two dozen different kinds commonly known to commerce in the islands.

PHILIPPINE OIL FIELDS

While it was known to the Spaniards that certain provinces of the islands were rich in mineral oil, the greatest discoveries were made but a few months ago by Americans. These newly-found fields are in Tayabas province, in Central Luzon, and

MOLECON DRIVE AT MANILA

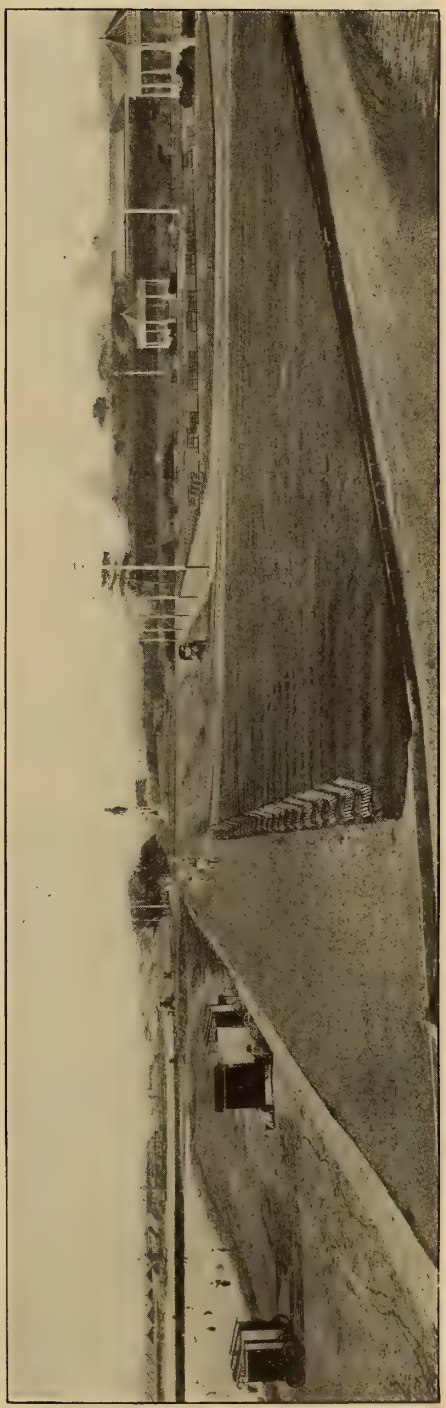
a number of companies are now beginning extensive operations.

The chief of the Philippine Division of Mines has issued a circular regarding the oil finds on the Tayabas peninsula. The report, in part, is as follows:

"The crude petroleum from Tayabas has a very light specific gravity, and only two or three fields in the world produce an oil comparable with it. It is very desirable for distillation, since it contains an unusually high percentage of gasoline and kerosene. During the reconnaisance oil seeps were seen in three distinct localities. On the Angus River there is a place where, when a pole is sunk into the bed of the river, oil rises to the surface and flows down the stream in iridescent patches. In the Vigo River the oil, accompanied by some gas, rises to the surface when a pole is thrust into the bed, this fact leading to the drilling of a well 21 meters deep, which encountered oil. Nearly the entire valley of the Vigo has been staked as claims. On the Bahay River there are places where the oil constantly rises to the surface and flows downstream. This valley is likewise staked with claims, but the fact that these localities are already entered should not deter others from investigating the peninsula. There are known to be many other oil seeps and gas vents, and the whole peninsula, which is 100 kilometres long, is worthy of close observation."

DENATURED ALCOHOL

In a recent number of the *Journal of Science*, published by the Philippine Bureau of Science, some interesting data are given. Perhaps the article fraught with the most possibilities, from a business standpoint, is that on industrial alcohol as a source of power in the islands. With the immense nipa swamps of the Philippines, the sap of which plant furnishes the greater part of all alcohol manufactured in the islands, the denatured article could be made at a very reasonable figure. This



THE LUNETA, AT MANILA, SHOWING OFFICERS' QUARTERS IN THE BACKGROUND, AND THE WALLED CITY, WITH THE LEGASPI-URDANETA MONUMENT IN THE DISTANCE

SAN MIGUEL ENTRANCE OF MALACAUAN PALACE, THE WHITE HOUSE OF THE PHILIPPINES

alcohol could be used to drive motors that are now driven by gasoline cheaper than they are now operated, and it is said that nearly any motor designed for gasoline can be run successfully with denatured alcohol. Experiments with this fuel were made with a gasoline road roller owned by the city of Manila, the machine being driven by the alcohol.

The nipa palm grows rapidly, reaching a height of four or five feet in a year. It takes four years for the plant to develop, and from that time it will flower regularly. In some places the plant is cut twice per day, and an average yield of a single plant is from thirty to forty liters.

Other subjects discussed by the Bureau's experts in this particular number of the *Journal* are calorimetry and the determination of the calorific value of Philippine and other coals from the results of proximate analysis, the economic possibilities of the mangrove swamp, Philippine raw cement materials and Philippine turpentine.

TRANSPORTATION—RAIL AND WATER—WATERWAYS AND WATER POWER

The building of railroads is, without a doubt, the most important step in the industrial history of the Philippines. Prior to 1891 but one road, a British concern, was in operation. But about three years ago the government granted concessions for the building of two general systems, one on Luzon and the other in the Visayan group—in all, about 1,000 miles of first-class lines, with standard rolling stock, heavy American rails, block systems, double-tracked terminals, etc. The Luzon line has gained control of the Manila & Dagupan line, the British road, and will operate it in conjunction with the new lines. This road runs from Manila to Dagupan, and in time it will be extended into Baguio, the summer capital. Branches now run from Manila to Antipolo, and to Cavite, around the bay. The new Luzon roads will run from Manila to Batangas City, another from Pasacao through Nueva Caceres and the Iriga and Albay hemp fields, terminating at Legaspi. This line will skirt Mayon volcano, always active, and the most perfect volcano cone in the world. The lines on Panay and Cebu islands, hemp and sugar districts, are now complete, trains being in daily operation.

The roads are expected to spread

contentment and ambition among the natives as no other one agency in any way could.

The cities, towns and commercial points of the archipelago are well connected by steamer from Manila, sailings being made daily by several competing lines. These vessels scarcely exceed 1,000 tons, yet there are one or two sumptuously appointed coasters, registering from 3,000 to 4,000 tons. The most objectionable feature in this otherwise commendable service is the poor accommodation, as a rule, for passengers.

The islands have few shipyards, most of which are situated about Manila. These plants confine themselves largely to repair work, and are unable to turn out new ships of any size. Motor-boat factories are unknown in the islands. Some day plants of this kind will prove highly profitable, as will the manufacture of small, light-draught river steamers.

Probably no country in the world has so many navigable streams as has the Philippines, and the coast boats, owing to their manner of construction, are poorly adapted to river work. Samar is a veritable network of rivers, which stretch into the rich interior and which are traversed only by hand-propelled bancas or barges. The Rio Cagayan, the largest and most fascinating river in the islands, which has its source nearly one hundred miles from Manila, flows northerly to Aparri, where it empties into the sea. Sixty miles from its mouth it seems as wide as the Mississippi at St. Louis. It passes through one of the richest valleys known anywhere.

The city of Manila has a perfect system of canals running in all directions. These canals are extremely valuable to business houses having their warehouses and go-downs along their banks. Cargoes are taken from the ships in the bay and transferred by lighter over these streams and the goods landed in storehouses, ofttimes far back from the bay shore in the

PANORAMA OF MANILA, A CITY OF A QUARTER MILLION POPULATION

ARTESIAN WELL, SUPPLYING A TOWN WITH WATER

heart of the city. The city recently appropriated a large sum to extend, dredge out and deepen and to wall up this valuable system. Persons are often transported from their homes into the shopping districts by water, the covered bancas resembling the gondolas of inundated Venice. Small motor boats will eventually carry passengers and tow barges over these canals.

There is sufficient idle water-power in the unharnessed mountain streams and falls in the islands to turn every wheel used in manufacture in the archipelago. Several of these falls are located near Manila, and plans are already on foot to utilize their energy. There is scarcely a province which has not from one to a dozen big waterfalls, nearly all of which will some day be valuable to man in more ways than one.

TAPIOCA INDUSTRY

Cassava root, from which tapioca is manufactured, is extensively found in and around the island of Mindanao. On the island of Basilan, across from Zamboanga, an American owns a large area, said to be profusely covered with the plant. He is building a factory to work up the material. The imports of tapioca into the United States are increasing, those for the fiscal year 1908 having been 49,806,092 pounds, valued at $1,408,177, against 43,647,731 pounds, worth $1,271,350, in 1907.

FISH AND PEARL INDUSTRIES

The chief meat component of the Filipino diet is fish. The consumption of sea food per annum is something surprising. Yet there are no organized companies engaged in fishing enterprises. Japanese fishermen are entering the field in goodly numbers, using native names as a blind to secure licenses. The Chinaman is the only one who smokes the fish and otherwise prepares it for the market.

CATHOLIC CONVENT IN THE CALLE REAL, WALLED CITY, MANILA

There are no canneries in the islands. Great banks of sardine fisheries are to be found off the coast of Luzon, and, altogether, the seas about the island, to say nothing of the fresh water, abound in some of the most appetizing fish known to man. Comparatively few white people in the islands eat fish, for the reason that they have no guarantee as to cleanliness; and the refrigerated article is often imported for their use.

The Sulu Sea is famous throughout the East for the beautiful pearls it produces. The pearl industry is the leading occupation of the Moros who live along the coasts of the southern islands. Frequently pearls are found worth many thousands of dollars. They pass from the fisherman to Chinese dealers ashore, who, in turn, send them to their associates in Singapore. Ultimately the pearls reach the London market, where they bring twice what the fisherman got for them. The natives use no armour or diving bells and, therefore, can fish only in shallow water. Now Americans, with finely equipped pearling sloops and modern diving apparatus, are meeting success in new, deep-water areas. A factory has been established in Manila which works up mother-of-pearl into various things, including buttons, boxes, salt cellars, and many other novelties. Its products are exported.

MANILA HEMP

As is generally known, the growth of hemp is the foremost industry of the Philippines. More Americans have taken up this business than any other one thing, because it requires less capital. The hemp plant belongs to the banana family, and Manila hemp thrives nowhere else in the world. The Philippine fields supply the entire world with raw hemp for manufacture into rope and cordage. In view of these conditions one would naturally judge that factories for working up the raw product are numerous. But such is not the case. It is very doubtful if there were more than a dozen rope-walks of any nature in existence when the Americans landed. And at present there is but one modern factory in Manila, that being owned and operated by Americans. A number of British firms, who have branch offices in Manila and agents throughout the

STORES OF THE UNITED STATES GOVERNMENT AT MANILA

provinces, do most of the buying and exporting. Exports aggregate anywhere from 200 to 300 millions of pounds annually, more than half of which comes to the United States. It is estimated that the average value of the total production is $30,000,000.

Until a year ago hemp had always been stripped by hand—a slow and wasteful process. It is cleaned by having a number of native labourers drag the stocks across a knife provided with iron teeth, thus separating the strands from the pulp. No sooner had the Americans arrived than inventors commenced to devise means to do this work by machinery, getting out a better grade of hemp, wasting less, and accomplishing more in a given time. Several of these inventors have been successful, and the machines are now doing excellent work, thus increasing the output. The tensile strength of machine-stripped hemp is nearly 50 per cent. greater than that of the hand-stripped.

Nearly all of the American hemp plantations are located on the Gulf of Davao, Mindanao. Here the American colony is considerable. These pioneers, strange to say, are far more successful with crops than are the older inhabitants, because they use scientific methods and are not afraid of work. Hemp will make a nabob of any one who goes into it with the right spirit.

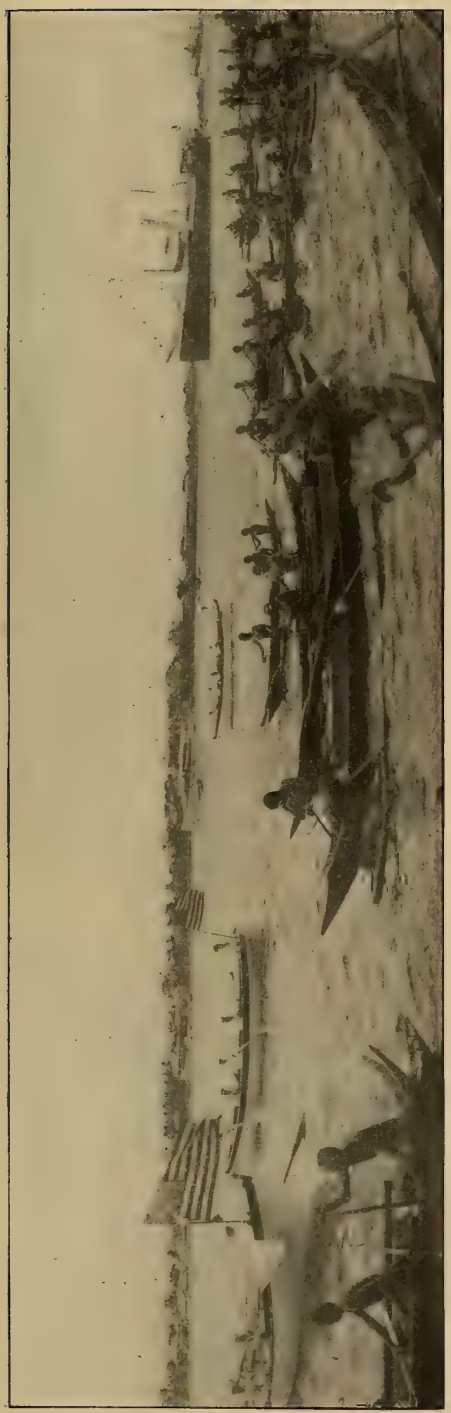
SUGAR AND TOBACCO

Few lands are as well endowed by Nature for sugar production as are the Philippines. Here cane soils are unequal and all other requirements favourable. But, strange to relate, all sugar, except that for local consumption, is refined abroad. The methods for extracting juice from the cane are indeed crude. Despite these adverse conditions, sugar is produced at from 60 cents to 90 cents per hundredweight. With modern machinery the product should be laid down in United States ports for 1 cent per pound. Good sugar lands are still plentiful in the islands, whereas all available territory in Hawaii and Cuba have long since been taken. As a proof of the richness of the soil stands the fact that, in the face of improper methods, the islands have been able to export 5,000,000 pounds yearly, besides supplying the domestic demand. The question of fertilization needs little, if any, attention. The best sugar lands are worth but from $100 to $150 to-day, and virgin acreage can be had much cheaper. Millions of acres of the public domain are lying idle. The demand for sugar in this country is increasing at an alarming rate, and it has been necessary for many years to import from abroad.

One of the most profitable crops for the planter in the Philippines to-day is tobacco. It is the third agricultural product, ranking next after hemp. Unlike sugar, the tobacco crop is cured and worked up into manufactured articles before leaving Manila, although a great deal of leaf tobacco is exported. Manila has some of the largest, as well as the most modern, cigar and cigarette factories in the world. Northern Luzon may be said to be one complete tobacco field. The largest hacienda there contains nearly 20,000 acres. Philippine tobacco, in leaf and cigar form, before the passage of the new tariff law, went to thirty-five different countries, including Turkey and Egypt. The fertility of the Cagayan valley, where most of the leaf is grown, is said to be due to the annual overflow of the Rio Cagayan, described elsewhere. Filipinos, men, women and children, are excessive users of tobacco. They consume 3,509,038,750 cigarettes yearly. The total value of leaf tobacco exported in 1906 was $1,767,365, while the total value of manufactured tobacco was $1,075,639.

MINERAL WATERS

The Philippines abound in mineral springs, some of which have medicinal effects. These waters are of all temperatures, from icy cold to boil-



A FIESTA DAY CELEBRATION BETWEEN AMERICAN SAILORS AND MOROS AT ZAMBOANGA, THE CAPITAL OF MINDANAO

CRUDE TRANSPORTATION METHODS IN THE PHILIPPINES; CARBAO DRAWING CARTS

IN THE BOTANICAL GARDEN AT MANILA

ing hot. They may be roughly classified as sulphur, saline, alkaline and purgative. They possess qualities equal to and in some cases superior to the well-known waters of Europe and America. The waters of Los Banos, a health resort up the Rio Pasig from Manila, contain sulphates of sodium, magnesium, potassium and calcium. These waters are being bottled and sold throughout the islands and the Orient.

COCOANUTS AND COPRA

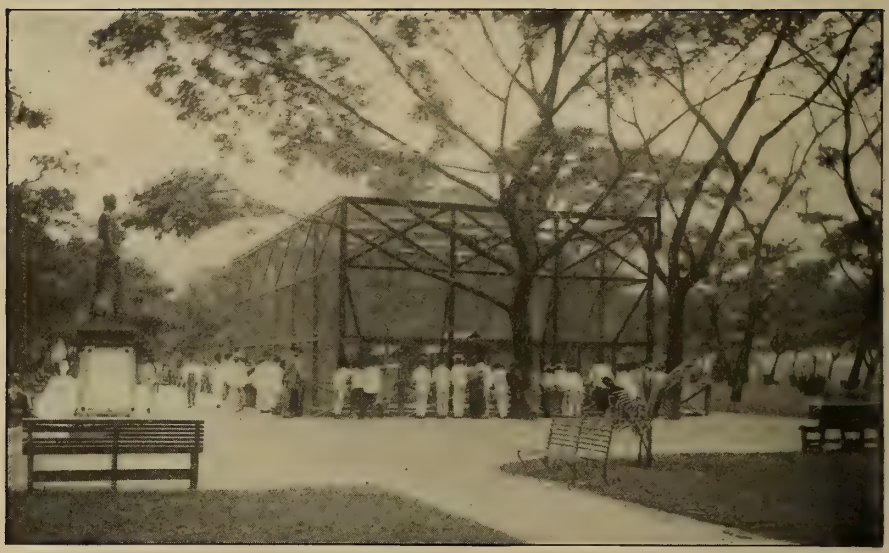
Cocoanut plantations, perhaps, offer one of the easiest livelihoods of any island industry, though the trees do not bear until five or six years old. After maturity, however, they require little, if any, attention, never

DISASTER DURING THE CONSTRUCTION OF THE STEEL BRIDGE AT FORT WILLIAM MCKINLEY

AN AMERICAN PLANTER IN HIS LAUNCH

failing to bring good incomes per tree for many years thereafter. Tayabas and the Camarines have, no doubt, the most extensive cocoanut groves. Small Chinese factories use great quantities of the product for various purposes; but the larger part of the yield is exported, mostly to

TROOPS ON THE MARCH IN THE EARLY DAY



BIRDS' CAGE IN THE MANILA BOTANICAL GARDEN

Europe, where French and German manufacturers are said to have succeeded in producing an excellent edible fat from the copra, the dried meat of the cocoanut. This substance, which is known as palmin, is used for cooking. It is a hard, snow-white vegetable fat of 100 per cent. purity. The price of palmin is said to be less than that of other cooking fats, and that of palmona, another butter product, much less than that of our butter. The output of one German factory is between 20 and 25 millions of pounds per year, which is usually sold far in advance.

LIBUL, WHERE A RESORT IS BEING BUILT NEAR THE HOT SPRINGS

PASSENGER TRAIN ON THE MANILA & DAGUPAN RAILWAY

AGRICULTURAL OPPORTUNITIES

Aside from those things already discussed, the general agricultural possibilities of the islands are bright and far-reaching. Before the American occupation the archipelago raised sufficient rice to meet all local needs, with a balance to export to China and other countries of millions of pounds. But of late years, due largely to a damaging rinderpest which has killed nearly all the beasts of burden, the government has been compelled to import great quantities.

NATIVE WOMEN LEAVING A PUBLIC MARKET

Wild rubber grows so profusely in Mindanao and other parts of the islands that the government troops frequently have a hard time in cutting their way through the mountain fastnesses. The natives gather it in a wasteful, destructive manner, shipping the harvest to Sandakan, the capital of British North Borneo, hard by. A number of American companies are being organized to exploit the rubber fields.

A fine grade of superior coffee is grown in parts of the archipelago. One Manila concern is now putting up the product for export.

Philippine pineapples are second only to the luscious fruit grown in Hawaii, yet there are no factories whatever for canning the production.

Batangas oranges, while small, are solid, sweet and satisfying, and fit to grace any table.

The fruits of the islands include a large and growing variety, some of which thrive nowhere else on the globe. One of these is the Philippine mango, considered by many to be the sweetest fruit in existence. These mangoes should bring a very high price in the markets. Some idea of their delicious excellence when eaten off the ice may be gained from the statement that American negro troops invariably prefer them to the watermelon.

There is scarcely a spice or a tropical fruit known which the islands do not produce. There are also many kinds of temperate-zone products which can be raised in that winterless climate.

The juices and oils from many flowers and plants there make the most expensive perfumes known to commerce. The oil from the ylang-ylang plant is shipped from the islands to the great perfumeries of France, where it commands an enormous price. Panglad, a grass plant, has never been made use of commercially. It produces an abundant juice, similar in taste and odour to that of the lemon. It has curative properties for coughs and colds, and the natives use it for seasoning foods and for making perfumes. Other grasses are said to be valuable to paper-making in-

BRIDGE ON THE FAMOUS MOUNTAIN ROAD TO BAGUIO

dustries, and a number of American firms are now experimenting with them and, in some cases, using them.

The Philippine Government is aiding and promoting agricultural pursuits in every way possible, expending large sums annually in the work. Experimental farms are conducted for making practical demonstrations as to what can be grown and what can be done with the steam plow, the thresher and other modern appliances.

SPONGE FISHERIES

According to the fishery expert of the Bureau of Science, the past year has marked the opening of the Philippine sponge fisheries from a commercial standpoint. Some 30,000 sponges were shipped from the islands during the year. The greater part of these were sold in Singapore for export to London. Samples of the sponges were taken to the United States Bureau of Fisheries, where they were favourably compared with specimens from Florida, Cuba and the Mediterranean. Samples were also taken to the wholesale sponge dealers in New York and San Francisco, who examined them with a great deal of interest.

NATIVE CLOTHS

The Filipino women produce some of the finest dress cloths known to femininity. The better grades are known as jusi and pina cloth, which are of a delicate gauze texture, and which bring good prices. Abaca is a coarse weave made from the hemp plant. These cloths have been going to Europe, but now that free trade has been established, there is no doubt but what the proper share of the output will come to the shops of the United States. American women are much taken with these weaves for summer wear.

THE BRENNAN GYROSCOPE

A NON-MATHEMATICAL EXPLANATION

By A. F. Dickinson, B. Sc.

MR. BRENNAN'S wonderful model experiments on mono-rail traction, the result of which he showed at the Royal Society's Soirée in 1907 and his recent successful exhibition of a full-sized car running on this principle, have drawn the attention of all those interested in railways to the possibilities of this mode of locomotion in the future.

The British Government is not excessively lavish in making grants, and the fact that both the British and Indian Governments have made grants to Mr. Brennan to carry out his researches is an indication that this system, when once brought to the commercial stage, will be of immense practical value. The model shown in May, 1907, was about 4 feet long and ran on two bogies, pivoted both vertically and horizontally, so that very sharp curves could be taken and a very irregular track run on. There were two gyroscopes, on horizontal axles, rotating in opposite directions and driven by electric motors supplied by accumulators.

The following information about the full-sized car recently shown at Gillingham is given by *The Engineer* at the time: The car is 40 feet long over the buffers, 10 feet wide, and 13 feet high from the rail level. Its weight, when empty, is 22 tons, and it carries a load of 10 to 15 tons. The motive power consists of two petrol engines driving dynamos, making a total of 100 horse-power. It is expected to run at 35 miles per hour and to be able to take inclines of 1 in 13. The car has a wheel-base of 20 feet, and is supported upon two bogies having wheel-bases of 5 feet 4 inches. The wheels, which are 3 feet diameter, are pivoted both vertically and horizontally. The gyroscope wheels, of which there were two, for reasons explained hereafter, weigh ¾ ton each and are driven at a speed of 3,000 revolutions per minute, being operated by electric motors on the fly-wheel shafts.

Many of those interested in engineering, on examining the ordinary theory of the use of the gyroscope to secure stability, are usually deterred by the amount of higher mathematics necessary to grasp the theory.

Below is given a non-mathematical explanation which, it is hoped, will explain the principles involved in the mono-rail system. Take the simplest case—that shown in Fig. 1—of a single gyroscope mounted on a stationary truck. In Fig. 1, *A* is a rotating fly-wheel, with a heavy rim revolving on a horizontal axle *B-C*. The ends of this axle have bearings in a ring *D-E*, to the bottom of which is fixed an upright spindle *F*, which is free to turn in a deep socket *G* fixed on the truck. To avoid confusion, throughout this article the turning motion of the fly-wheel *A* on the *B-C* will be called *revolution* and that in the spindle *F* in the socket *swivelling*.

In Fig. 2 the observer is supposed to be looking at the rear of the car, and the fly-wheel is revolving in the direction which the car wheels would have when going forward. The axle is in the horizontal position, across the car at right angles to the rail.

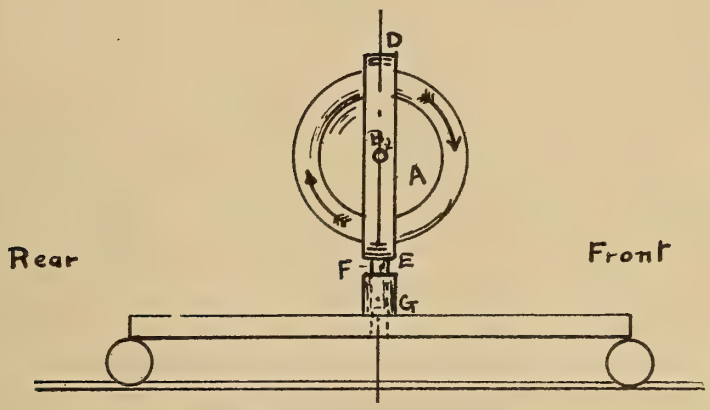


FIG. 1.—SINGLE GYROSCOPE ON TRUCK

The principle involved is the well-known one which may be expressed as follows: If a body is in motion in a given direction, that motion will continue in the same direction unless acted upon by some external force.

Now if the fly-wheel *A* is revolving and the car is suddenly tilted sideways through a right angle to the position shown in Fig. 3, the rotating movement about a horizontal axis will continue in the same direction as before, only the rotation is about the spindle, which is now horizontal, and the revolving wheel, resisting the tilting, has communicated its motion to the mass of the combined wheel and ring, and, in doing so, has ceased to revolve about the axle.

If we imagine the tilting to be instantaneous, it appears only natural that the mass should continue revolving in the same direction as before, and that this is actually the case can be shown by experiment.

Now if the car, instead of being tilted right over on its side, is tilted over a little to the right, what happens? The result is just what we might expect from the previous observation. The wheel resists the tilting and is reduced in speed, while to make up for this the wheel and ring begin to swivel slowly round the spindle in a clockwise direction, as observed from above.

Further, on the well-known principle to every action there is an equal and opposite reaction, since, if we tilt the car, the gyroscope swivels to the right; if we force the gyroscope round on the spindle the car begins to tilt in the opposite direction—that is, begins to right itself and then to tilt towards the left.

Fig. 5 shows a car with a gyroscope with a fly-wheel, and a handle attached to the gyroscope. Now, if there is a man stationed on the car to work the handle, and if, every time the wheel begins to swivel round owing to the tilting of the car, he forces it round further or "hurries" it, the car will right itself every time, and by this means he will be able to keep it upright, rocking a little from side to side.

Now, if instead of a man working the handle we have some automatic

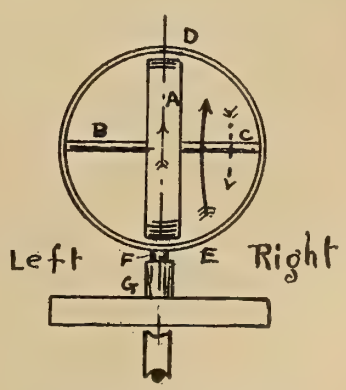


FIG. 2.—END VIEW OF SIMPLE GYROSCOPE TRUCK

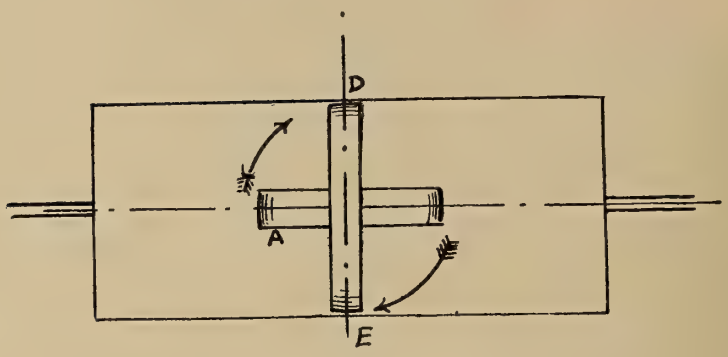


FIG. 3.—GYROSCOPE CAR TILTED SIDEWISE

arrangement for doing so, the car can be made to stand up by itself. For instance, if a spring be attached to the handle, as shown in Fig. 6, when the gyroscope is in its normal position the spring has no effect; but when once the car tilts, the gyroscope begins to swivel, the leverage is increased, or the "precession," as it is called, is "hurried." This causes the car to be lifted to the upright position again and to begin to tilt towards the other side. This tilting motion again makes the gyroscope swivel to the other side, and the process is repeated. We might substitute a pendulum for the spring (Fig. 7), thereby obtaining the same result. With this arrangement, however, it will be found that the swings become longer and longer until the car falls over sideways. This will not happen if the swings are damped by some means; as if, for instance, the pendulum is immersed in water. A model which will show the principle of the mono-rail car can easily be made with a small gyroscope, if fixed in a frame such as is shown in Fig. 6. This will serve to illustrate

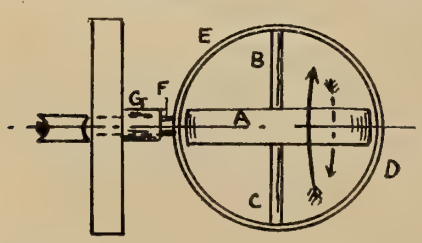


FIG. 4.—END VIEW OF CAR TILTED SIDEWISE

both the spring and the pendulum method.

It is obviously clumsy and unsuitable in many ways to have the pendulum arrangement on a running car. Mr. Brennan has, therefore, produced the same effect by means of rollers on the axle. In Fig. 8 these rollers are shown at *X-X* and *Y-Y*, these rollers being loose to rotate on the axle, but with a certain amount of friction.

Considering *X, Y*, suppose the car to tilt downwards the right. *Q* is a strip of circular form which presses on *X, Y* and tends to tilt the gyroscope, causing it to swivel in a clockwise direction, at the same time pressing down on *Q*. Owing, however, to the friction between the roller and strip, the gyroscope runs along the strip *Q* and so swivels round, as if it were forced or hurried. The result is as before—the car is brought upright and tilted to the left, overshooting the upright position so that *P'* comes up and presses on *X'*, repeating the process. The gyroscope swivels round again, and is similarly pressed by *Q'* and *P'*. In this way there is always a slight roll of the car, but this is so slight with powerful gyroscopes as to be imperceptible.

In Fig. 9 there are two gyroscopes shown. If a single gyroscope is used, when the car goes round a curve the gyroscope will keep in the same direction, and so will turn relative to the car; to a person in the car it would seem to be swivelling (Fig.

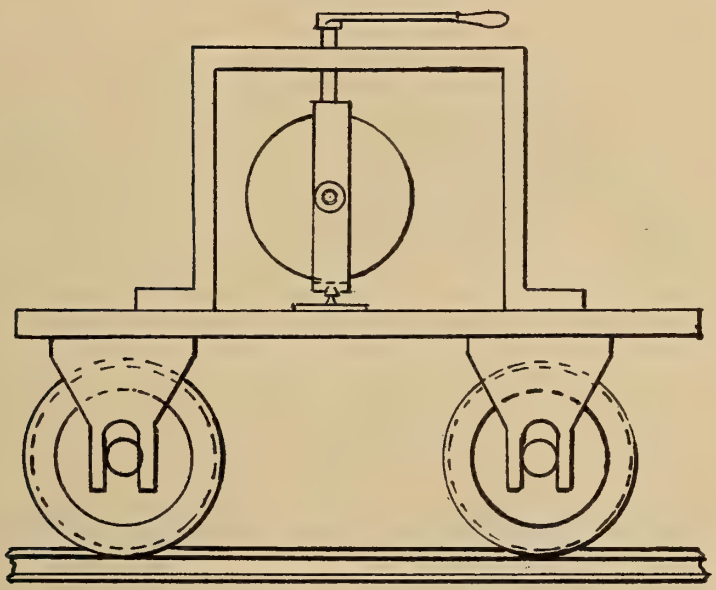


FIG. 5.—CAR WITH HAND-CONTROLLED GYROSCOPE

10). The result would be that the gyroscope would in time get out of its position at right angles to the rail and the arrangement shown in Fig. 8 would be useless, while the gyroscope itself would have less righting power. It is, therefore, necessary that, when the car turns round as it goes round a curve, the gyroscope should turn with it.

The arrangement by which this is accomplished is shown in Fig. 9. *K*, *K'* are two fly-wheels revolving on the axles *L*, *L'*. They are driven by electric motors not shown in the diagram. They are free to swivel on the spindles *S*, *S'*; but these spindles are connected by the arms and toothed segment *M*, *M'*, so that when one swivels the other is given an equal and opposite swivel. The arrange-

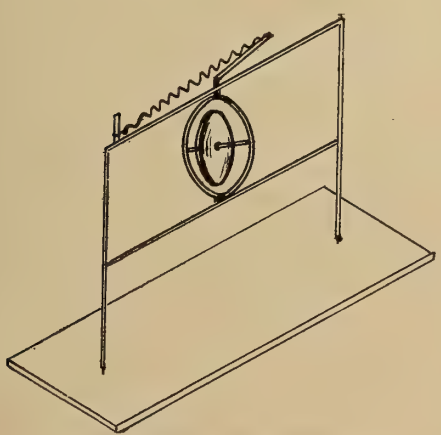


FIG. 6.—GYROSCOPE WITH SPRING CONTROL

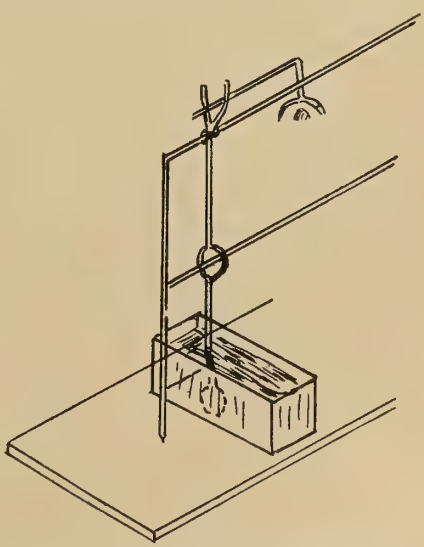


FIG. 7.—GYROSCOPE CONTROLLED BY PENDULUM IMMERSED IN WATER

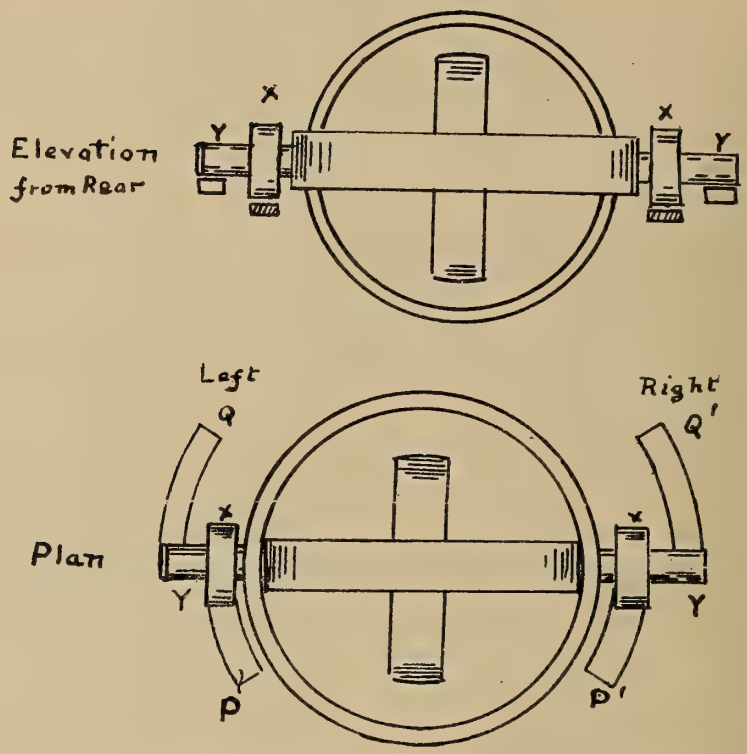


FIG. 8.—ARRANGEMENT OF ROLLER SUPPORT FOR GYROSCOPE

ments for hurrying the swivel or precession are the same as those explained above, though they act on only one gyroscope at a time, and this through the gearing turns the other on its vertical axis to an equal extent. Suppose the car to tilt down to the right; then, as before, the strip *Q* presses on the roller *Y* and tends to tilt the gyroscope, causing it to swivel in a clockwise direction and press *Q* down, at the same time running along *Q*, and thus forcing the procession. The car is brought upright and overshoots again, calling into play *P'*, which presses on X', and so the process is repeated.

The whole frame *Z* is pivoted on a longitudinal axle *O*.

With this apparatus, when the car

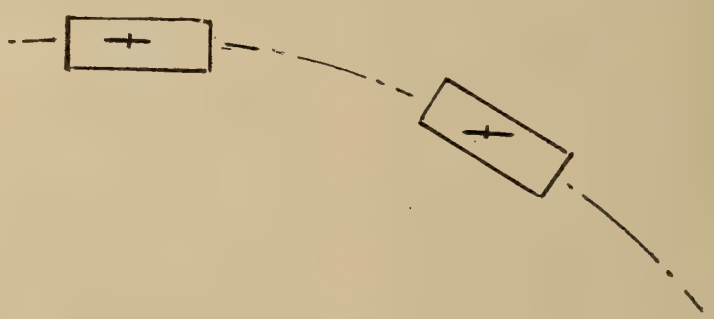


FIG. 10.—POSITIONS OF GYROSCOPE ON CURVE

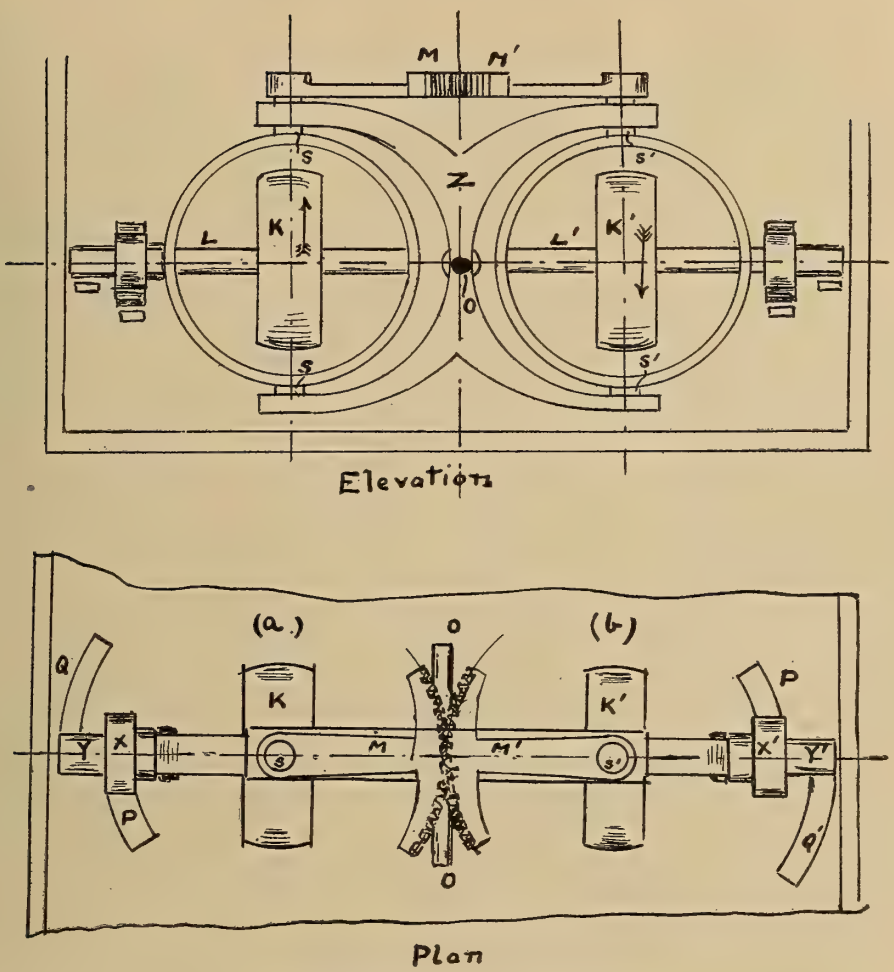


FIG. 9.—ARRANGEMENT OF TWIN GYROSCOPES

goes round a curve the whole frame swings round with it, for, as the flywheels are opposite in their directions of rotation, their effects neutralize each other.

So perfectly does this overcome the difficulty that there is no perceptible heeling or rocking, even when going round the sharpest curves. It is interesting to note that Mr. Brennan's patent specification for this application (No. 27,212, of 1903) of the gyroscope also contemplates its use both for aeroplanes and submarines, and also for vehicles with one wheel, thus covering future applications. In the latter case a second set of gyroscopes would be used to control the tendency to tilt backwards and forwards.

POWER PLANT WASTES

PRACTICAL INSTANCES OF PREVENTABLE WASTES

By Percival Robert Moses

SPECIFIC instances are usually more convincing than discussions of the abstract, and, at the same time, may point the way toward the remedying of defects in other places where similar conditions exist.

With these objects in view a number of plants of different types will be described. The defects and preventable wastes found will be pointed out and the remedial methods adopted or recommended will be described. More or less repetition is inevitable, as the same wastes will be found in many plants, even though these plants differ widely in their functions. Every one of the plants discussed is an actual plant in which the defects and wastes noted actually existed and were reported on by the writer. Each waste was preventable, and just as truly a waster of capital as the San Francisco fire, but with no excuse for its existence but lack of knowledge or neglect.

It is regrettable but true that in several instances these wastes continue, notwithstanding the fact that they have been clearly pointed out and their existence acknowledged. The potential power of the world continues to be unwarrantably wasted, and the parable of the ten talents might well be applied. It is true that some of the waste is of small consequence in the individual plant, but when multiplied by the hundred thousand it becomes of national significance.

WASTE IN A SALT PLANT

The first plant to be described is a salt block in Michigan. In this plant salt is obtained by driving fresh water down through the salt beds underlying great extents of territory and bringing it up through pipes to the evaporating plant. For years salt had been made in this plant with the evaporation carried on under atmospheric pressure. Steam was supplied from hand-fired boilers. The fuel used was bituminous slack, and it was stored in deep piles, exposed to the weather.

The preventable wastes in this plant were numerous. The evaporation of the salt brine should have been carried on, in part, under the multiple-effect evaporation system, such as is used in sugar and similar processes. In this system the vapour generated by the evaporation in one pan is used to evaporate the water in the next pan, in which a slight vacuum is carried, and so on through four or even eight effects.

For certain character of salt grain, such as is needed for butter and packing purposes, multiple evaporation is not applied to advantage; but for ordinary table salt it is highly satisfactory, and results in a saving but little less than would appear to be theoretically possible.

A second waste was caused by the storing of the soft slack in deep piles. This resulted in spontaneous combustion, turning the bottom of the pile into ashes and gradually burning away the storage dock. There was also the waste due to weathering.

A third waste resulted from hand-firing, not only because of wasteful handling of fuel and air, although these were important causes, but be-

cause of black smoke and cinders, which, mixing with the salt, caused commercial loss in the selling end of the business, the black specks proving objectionable. The smoke was practically stopped and a 10 per cent. economy in fuel obtained by the installation of mechanical stokers of the under-feed type with forced draft.

A fourth waste was in the handling of material: there was not a conveyor in use in the plant except for dragging the salt through the grainers. There was also no method of mechanically transporting the finished product from the evaporating pans to the storage piles nor from the piles to the packing department, etc. Conveying systems are used for such purposes elsewhere with great success. Coal was also handled by hand trucks—50 tons a day.

In this plant the only steam wastes worth noting were the failure to save the high-pressure steam drips and to properly heat and insulate the long lines of steam pipes. It is true, there were many inefficient pieces of steam apparatus, such as duplex simple pumps, in use; but as their exhaust was fully utilized in the evaporation of brine, their inefficiency did not result in waste. In this plant it is evident that the defects were defects of design rather than management; and, in fact, the plant was operated in a highly efficient manner considering its planning and arrangement.

DEPARTMENT STORE

The second equipment to be discussed is that of a large department store of New York City, where a complete heat, light, power and elevator plant is operated.

The building covers a plot over 300 x 200 feet, and varies in height from four to six stories. When this plant was first inspected the conditions were almost incredibly bad. There were five boilers, three horizontal return tubular ones, two of 175 horse-power each, one under which papers were burned of 150 horse-power, and two water-tube boilers of 300 and 250 horse-power, respectively, three electric engines, a high-duty elevator pump and two compound duplex elevator pumps, a refrigerating machine of the compression type and quantities of small steam duplex pumps for boiler feed, house service, drain, brine, ice-water, etc. The steam mains leaked at nearly every joint; there was no damper regulator; the horizontal boilers were so full of hard scale as to make the cutting out of the tubes an absolute necessity. The water-tube boilers were in an almost equally bad condition.

Although the exhaust steam from the electric plant, pumps, etc., was used for heating, all the steam condensed in the radiators—i. e., the returns were allowed to flow to the sewer; and as if this were not enough, it was found that one of the tubes of the feed-water heater was corroded through and feed-water was being forced into the sewer under a pressure of 80 pounds per square inch. All the pumps, without a single exception, leaked both steam and water, and the drain pump—there was only one in semi-operating condition—broke down shortly after the first inspection, and the returns filled the cellar to a height of over 8 inches before the pump could be patched up enough to run.

The plant was operated only until midnight and gas burned after this time—several hundred dollars' worth a month. One of the engines was out of order, and the valves on one of the others were so set that one end of the cylinder did more work than it ought to and the other practically none.

The compound elevator pumps used at night and on holidays leaked so badly on both steam and water ends as to be nearly useless.

The cellar was continually full of vapour, to such an extent as to cause warping all over the first floor. Because of the excessive humidity, due to escapes of steam, neither the boiler nor the engine room was fit to work

in and became a perfect inferno in summer, so that it was necessary to offer special inducements to get men to work, and more men were employed than would otherwise have been required. This plant was typical of the worst conditions—preventable wastes existed in fuel, labour, water, steam and maintenance. It was true, also, that the fuel used because of boiler and draft conditions was more expensive than should have been necessary.

Almost all of these conditions have been remedied. The first thing done after cleaning out boilers and putting them into safe and efficient operating condition was to take the oil out of the exhaust steam and pump the returns back into the boiler. All the steam leaks were permanently stopped. Turbo blowers were installed to remedy the draft deficiency. The disabled engine was repaired, and because of the improved condition of the boilers the steam pressure on these was raised from 80 to 125 pounds, resulting in very greatly increased efficiency of engine and elevator operation. Of course, the feed-water heater was repaired, and the water bill dropped so suddenly that the head bookkeeper sent down to inquire if the meter had stopped operation. The plant was operated twenty-four hours a day and the gas bill saved, with but slight increase in cost of plant operation. The use of a low-grade fuel was recommended, but this has not yet been adopted, so this waste still continues. Other minor wastes, such as failure to save drips from steam pipes, leaks from water-closet flush valves, etc., have been remedied, so that now the plant may be said to be in an efficient condition, even if not all the wastes have been stopped.

Of greater importance, perhaps, is the fact that there is now always a spare unit in every part, boilers, engines, dynamos, pumps, etc., so that the apparatus can be maintained, with proper supervision, in first-class condition, free from danger of accident or breakdown.

CLUB-HOUSE

The third building is a club, occupying a plot 100 feet square on upper Fifth Avenue, New York City.

This club contains a complete lighting, heating, ventilating and refrigerating equipment. It is of modern design, hardly four years old, and it is highly wasteful. The wastes are different from those of the department store just noted, because these were largely due to operation, while the club wastes are mainly due to mistakes in design.

To begin with those in connection with the ventilation and heating. No provision is made for separating these two functions, and the only way that heat can be supplied to a room is by drawing in air from outdoors (at outdoor temperature), heating it to 100 or more degrees F. and blowing it into the room. If, instead of this, direct heating surface had been placed in the rooms, or if provision had been made for re-circulating the air, a great economy in fuel would have been effected, because under present conditions forced ventilation is not needed during three-quarters of the time when heat is required, and the bringing in of quantities of cold air and the heating of this air means great fuel waste.

The second waste is in connection with the electric equipment. The electric distribution system is on the two-wire, 240-volt plan, requiring incandescent lamps designed for this voltage. Lamps designed for 240 volts require one-third more electric energy for the same amount of light than do ordinary carbon filament lamps designed for 120 volts and over three times the energy required by tungsten lamps. So far, no tungsten lamps of small candle-power—20 candle-power or less—have been designed for 240 volts, hence it follows that the club is forced to use three times as much electricity as it would otherwise need for lighting merely because the original contractor saved the cost of the third wire needed for a three-wire

system. Of course, this condition can still be remedied, but at considerable expense.

The third waste is in connection with the refrigerating plant. This plant requires a large quantity of water for condensing purposes, and while this water should be saved and used in the club, actually a very small part is saved and used in the boilers. The rest is wasted absolutely without good reason, except failure to install a tank to receive the condenser discharge. Thus a waste of three to four dollars a day has been going on for four years because of lack of knowledge and of failure to install a tank costing, with connections, a few hundred dollars. Is it a wonder that New York needs a 160,000,000-dollar water-supply system with such conditions existing?

It may be noted, *en passant*, that the same condition has been found in a large poultry and game supply house, and also in a prominent hospital.

The fourth waste is in connection with the elevators. The elevators are of the plunger type, operated by an electric rotary pump. This pipe derives its electricity from the plant, and, because of its size, it is necessary to run constantly two engines instead of one. Under the existing conditions this can only be avoided by the installation of a storage battery. This plant is well operated, and while there is an excess in the amount of labour over the usual allowance, this is partly due to the spread-out arrangement of the equipment and the unnecessary division of the plant into separate rooms. The frequent waste of using too expensive fuel is evident in this plant, but this is due to the incorrect proportioning of grate surface. There is less than 1 square foot of grate to 5 rated boiler horse-power, and as it requires about 4½ pounds of low-grade fuel per horse-power and not more than 15 pounds may be burned per square foot per hour without mechanical draft, it is evident that insufficient grate surface means expensive firing if the boilers are to be worked at anything near their rated capacity.

Here, then, is a modern club of the highest grade, in the most expensive location, able to secure the best engineering talent, handicapped from the start by failure to do so. Result: poor design and an operating expense, until remedied, of at least 50 per cent. more than it would have been with correct planning.

HOSPITAL

The fourth building is a large hospital in the middle of Manhattan Borough, New York City, the various buildings of which occupy a plot 200 x 300 feet.

Here we find, or rather found, as the defects have all been just remedied: waste of returns from heating system, extra expensive fuel, waste of water and inefficient pumps.

Besides these familiar wastes we found new ones, which, however, are frequently found elsewhere, viz., the use, for heating water, of steam derived directly from the boilers, usually called "live" steam, while quantities of exhaust steam equally available for the purpose from engines and pumps were allowed to pour freely out of the exhaust pipe. The reason for this waste in this hospital was that insufficient coil surface had been provided in the hot-water heaters; consequently, steam of a higher temperature was necessary to keep the water hot at periods of heavy demand.

This difficulty was easily remedied by installing a water heater with ample heating surface, and now the lower-temperature exhaust steam does the work easily.

The inability to burn low-grade fuel was cured by adding 100 feet to the smokestack. This cost $1,000, and will save over $4,000 annually.

The use of carbon filament lamps for electric lighting instead of tantalum and tungsten lamps was a source of preventable waste, because the load was such that at times two engines

were needed, whereas with higher-efficiency lamps one would suffice. It was also found that high-candle-power lamps could be replaced by 8 and 12 candle-power lamps with suitable reflectors with better lighting results and a great reduction in the consumption of electricity.

One source of waste still remains. The boiler plant is old and divided into seven boilers of 40 horse-power each. The boilers are now safe for 70 pounds pressure only; hence the engines operate at low thermal efficiency, and there is an excessive waste of heat, due to the large number of furnaces in operation. As the remedy for this is to scrap the old boilers, and these are safe even after more than twenty years' service, the last waste will not be prevented for a while.

At another hospital, about a mile further uptown, a saving of $464 a month in fuel out of a total of $696 was made by similar changes to those noted in the foregoing. In this latter instance the returns were not being wasted, but instead all the high-pressure traps were leaking. These were intended to allow condensation to escape, but to prevent the discharge of steam from the high-pressure steam lines, and as a consequence of the leaks in the trap valves pressure accumulated in the feed-water heater, causing the feed-water to overflow in a steady 2-inch stream of boiling water to the sewer. In this plant pea coal, at $4.10 per ton, was being burned, and was replaced by fuel at $2.40 per ton, and less of the latter was burned after the changes were completed. The latter hospital was only built a few years ago, so the board of governors had a right to expect apparatus of most modern design.

Here the trouble lay not only in the design, but mainly in the operation. Carelessness, neglect and ignorance were the causes of preventable waste, and the design was only at fault in the hot-water heating arrangements and in the design of the electric two-wire system, which was arranged for 240 volts, as in the club previously described.

APARTMENT HOUSE

The next example is an apartment house, ten stories in height, covering a plot 80 by 125 feet, with two passenger elevators and a complete electric and refrigerating plant. It is a relief to find here that the returns are saved, that the hot water is heated by exhaust steam almost wholly, and that the labour bills are moderate; but we find pea coal, at $4.10 per ton, being burned where fuel at $2.40 would do the work equally well. A 100-kilowatt-engine dynamo is operated all day with a steady load of about 10 kilowatts, because no storage battery has been provided, nor any smaller unit. The ashes are being removed by private ash men, although it is part of the city's work to do it, and it is done by the city in almost every other similar house. The two-wire, 240-volt system is used, with inefficient lamps, although a three-wire system of wiring is installed. The owner and engineer evidently do not know how to balance the three-wire system, or do not want to spend the few hundred dollars necessary to attain this end. In this plant a saving of $3,600 a year is readily obtainable, but it is necessary to spend $5,000 to get it. If it had been properly planned to begin with, there would have been no extra expense, as the cost of the battery would have been balanced by the reduction in cost of the rest of the equipment. As the building is about six years old, it has suffered a loss of about $20,000 already from lack of engineering knowledge.

MANUFACTURING PLANTS

In a sugar mill in Porto Rico, owned by New York bankers, the electric plant supplies electricity for operating a great part of the machinery in the mill other than the big mills, and also large electrically-driven pumps, which supply water for irrigating the fields. For sev-

eral years after the starting of this plant the exhaust steam from the electric engines was condensed. This was the original plan, and it was based upon the assumption that the cane pulp would furnish ample fuel for the mill. It was found that with the most modern methods more sugar than formerly was extracted from the cane, leaving less material for fuel, hence extra fuel was needed for evaporating processes, etc. It was decided to utilize the exhaust from the electric plant in the evaporating process, and this change resulted in a saving of at least 75 per cent. of the heat formerly wasted in the condenser.

MANUFACTURING ESTABLISHMENTS

In a metal stamping factory in the Greenpoint section of Brooklyn a leak was found around the piston of the engine, due to rings improperly fitted. These rings were made tight, and a saving of 20 per cent. in the fuel was effected immediately.

In another factory in Brooklyn, where baking powder is made, the engine, a 200 horse-power Watts-Campbell Corliss, was operating at 60 pounds steam pressure, although the boilers were good for 100 pounds and steam was not cut off by the governor until about five-eighths of the stroke. In consequence, the steam did not have a chance to expand, and great waste resulted. The indicator revealed this condition, and, when corrected, the steam is cut off at from one-fourth to one-third the stroke, and the expansion is practically complete. In this same equipment the returns are still being wasted, but will not be in a few months. The system of power transmission involved such a quantity of belting and shafting that the loss in friction was about 120 per cent. of the useful work—i. e., out of a total of 154 horse-power 70 horse-power was actual work and 84 horse-power was waste, which state of things is now being corrected by the installation of electric drive.

FOUNDRY

In a large foundry, spread over 20 acres, the principal waste in power manufacture arose from the use of scattered high-speed engines supplied by long lines of steam pipes. These are now about to be replaced by electric motors supplied from a centrally located plant, consisting of high-efficiency gas-producer and gas engines and electric dynamos. In this central plant part of the heat contained in the exhaust gases and jacket-water will be saved, so that efficiency of generation of power should be high.

A serious source of waste was also found in the escaping gases from the air or open-hearth furnaces used in melting iron. This heat might readily be used for the generation of steam by passing it through a boiler. Another waste arose from failure to foresee the very rapid growth of power requirements, making it necessary to purchase electricity from a central station for part of the load.

Such instances might be multiplied indefinitely, but sufficient examples have been given to show that the wastes described in the earlier portions of these articles were real, and usually readily preventable. Such wastes should not exist. Those arising from mistakes in design are generally due to lack of knowledge of the practical side of plant operation. The designing engineer and the contracting engineer seldom have any intimate knowledge of the practical details of plant operation. They design a plant, it is installed, operates, and that is all they hear about it. The chief engineer may, and often does, change the equipment so as to improve its efficiency; but if this is not easily possible he worries along somehow, and nobody knows whether waste occurs or not unless conditions get too bad and some outside expert is invited in to tell "why it costs so much."

I will close by citing one such case. A prominent evening newspaper built a model building for its own occupancy and for other offices.

The owner found that the cost per year for heat, light, power and ventilation was nearly $25,000, whereas in other similar buildings the cost was less than half this amount. Investigation showed that preventable wastes existed on every hand.

A complete night-and-day engine-room force was maintained, with boilers supplying steam at high pressure for steam pumps for plunger elevators, while electricity was purchased to the tune of over $12,000 per year from the central station of a company. Boiler steam was used for heating, and at the same time the ventilating fans were driven electrically instead of using steam-driven fans and allowing the exhaust to be used in the heating system. Ordinary carbon-filament lamps requiring 3.1 watts per candle-power were used instead of tungsten lamps using 1¼ watts per candle-power. Coal costing $3.25 per ton was used instead of coal at $2.40. Generally where there were two ways of operating the most expensive was chosen.

What was the reason for this? Simply ignorance of practical conditions. The boilers, the pumps, the ventilating system, the electric equipment—all were the best of their kinds; but no consideration was given to their mutual interdependence. It probably never occurred to the man responsible for the installation of boilers and pumps that these would require engineers and firemen night and day, and if no electric plant was to be installed it would be better to use electric elevators. On the other hand, the electrical designer apparently never thought that there was to be a complete power plant operating, and the operation of electric engines and dynamos would make absolutely no difference in the labour cost and very little in the coal cost. Under present conditions steam has to be made in the boilers for heating, while with the electric plant operating the exhaust would have been ample for the greater part of the time. The ventilating man apparently did not realize that the fans would be used mostly when heat would be required, and that with a high-pressure steam plant already in operation it would be much cheaper to drive fans by steam and use the exhaust for heating than to purchase electricity at 5 cents per kilowatt-hour and use boiler steam for heating. It is quite probable that they did realize these facts and presented them to their client, and the owner was responsible for the aggregation of mistakes.

However this may be, the result is an annual preventable waste of between twelve and thirteen thousand dollars, or, to put it another way, the preventable waste is more than 100 per cent. of the necessary expense, and because of existing contracts this waste will continue for at least four years.

SUGGESTED METHODS OF ESCAPE OUT OF A SUNKEN SUBMARINE

By George Frederick Zimmer, A. M. Inst. C. E.

HOWEVER perfect the design and equipment of a submarine may be, its navigation will probably never be free from danger to the crew. To minimize this danger, as well as finding means and ways of escape in case of foundering, is a task which exercises the minds of many practical naval constructors and engineers.

As yet it is only a few years since submarine navigation has made any practical progress, and already the toll of human lives claimed in sunken submarines is heavy on both sides of the Channel. In March, 1904, off Spithead, submarine No. A1 went down in consequence of a collision with the Berwick Castle, with the loss of the whole crew of eleven. In June, 1905, submarine No. A8 went down off Devonport with a crew of eight, out of which only four were saved. In October of the same year the A4 met with a mishap, with, fortunately, no loss of life. In February, 1906, submarine No. A9 collided, and again in July, 1908, the same submarine had a misfortune off Portsmouth, both times, fortunately, without loss of life. Again, quite recently, on July 15, submarine No. C11 was lost with eleven hands, only three being saved out of a crew of fourteen.

The principal causes of submarine foundering are (1) shot holes, or collision with other vessels, when only slightly submerged, which would damage the upper portion of the hull; (2) collisions with submerged rocks or wreckage, which would damage the lower half of the hull; and (3) breakdown, or failure of machinery to act in the case of a submerged vessel, and so make it impossible for it to rise.

The first of the causes are undoubtedly the most serious, as through a leakage in the upper half of the hull the water would gradually expel and replace the whole of the air in the vessel.

In the second case, where the submarine is holed in the lower half, the water, when rushing in, will not expel but only compress the air, until the air pressure is equal to the water pressure, due to the depth of submersion.

The third case, in which the vessel lies at the bottom of the sea, helpless but intact, is, perhaps, less distressing than the other two disasters, as there would be light available, and any operations could be better conducted in light and under absence of water.

Let us now see what are the dangers confronting the crew and what means can be adopted to save them.

Firstly, in case the vessel is filled, or partly filled, with water, the crew are in danger of suffocation by chlorine and other poisonous gases generated by contact of the sea-water with the electrical accumulators or storage batteries.

Secondly, what means should be adopted to prevent the men from drowning in the holed vessel, and

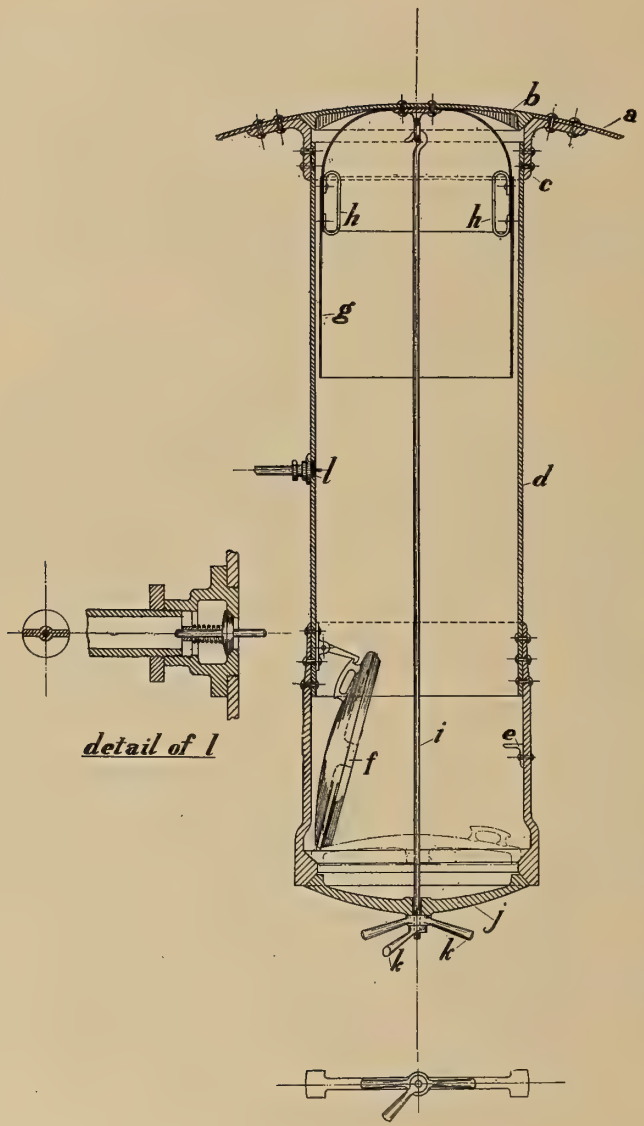
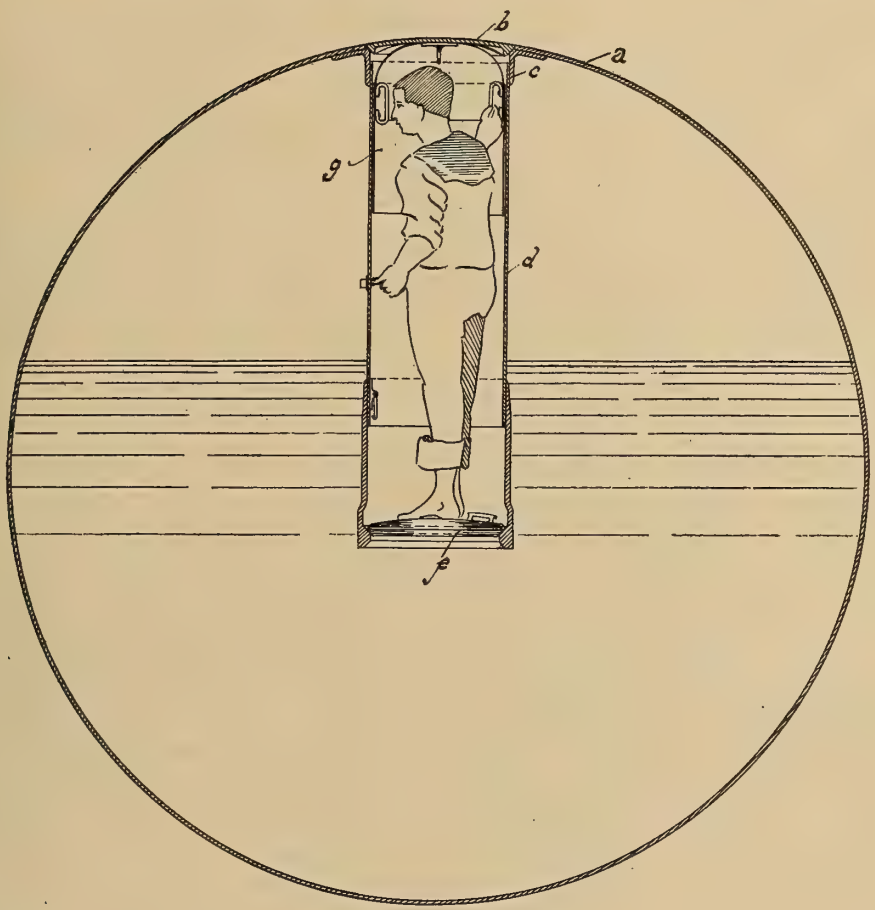


FIG. 1.—CYLINDER WITH LIGHT METAL HELMET; ALLOWING ONE MAN TO BE RESCUED



MAN IN CYLINDER READY TO RISE

how can an escape out of the vessel be effected?

It is well known that chlorine gas is immediately generated on sea-water coming into contact with accumulators, and that a very small quantity of this gas in the air will cause violent coughing and make work impossible, whilst a little more will cause suffocation. Now, fortunately, the first of these problems—the prevention of suffocation—has practically been solved. The solution which has been accepted by the British Admiralty consists of a kind of diving helmet with conical rings to fit over the shoulders, which finally extends into a jacket of waterproof material, which is to be worn by each man in case of emergency. This helmet is the invention of Commander S. S. Hall, R.N., of the submarine service, and of Staff Surgeon Oswald Rees, of H. M. S. *Mercury*. It is manufactured by Messrs. Siebe, Gorman & Co., Ltd. The apparatus is as follows: The jacket, which forms the extension to the helmet and which fits loosely over the body, has a pocket inside in front, in which is a case with two compartments which contain a combined air purifier and oxygen generator. This is charged with a substance called oxylithe, which has the peculiar property of giving off oxygen gas if brought in

contact with the moisture of the breath of the wearer and forming a caustic alkali, which latter absorbs the carbonic acid gas of the air exhaled and forms alkaline carbonate. In this way the air inclosed in the helmet is purified from the carbonic acid gases and the oxygen is replenished, and hence the air can be inhaled over and over again.

In addition to giving the wearer the necessary atmosphere to live in this jacket acts as a life-buoy to keep him afloat if the vessel is partly filled with water, and also after his escape out of the submarine, if this can be effected. The helmet is fitted with an air-tight window, and the sleeves of the jacket are provided with rubber tightly fitted round the wrists, like a diving suit, whilst a belt round the waist holds the loose jacket in place.

In connection with the helmet just described a system of air traps has been experimented with by the British submarine crews at Whale Island, where special diving tanks have been so fitted as to present as nearly as possible the same conditions as on a submarine having met with disaster.

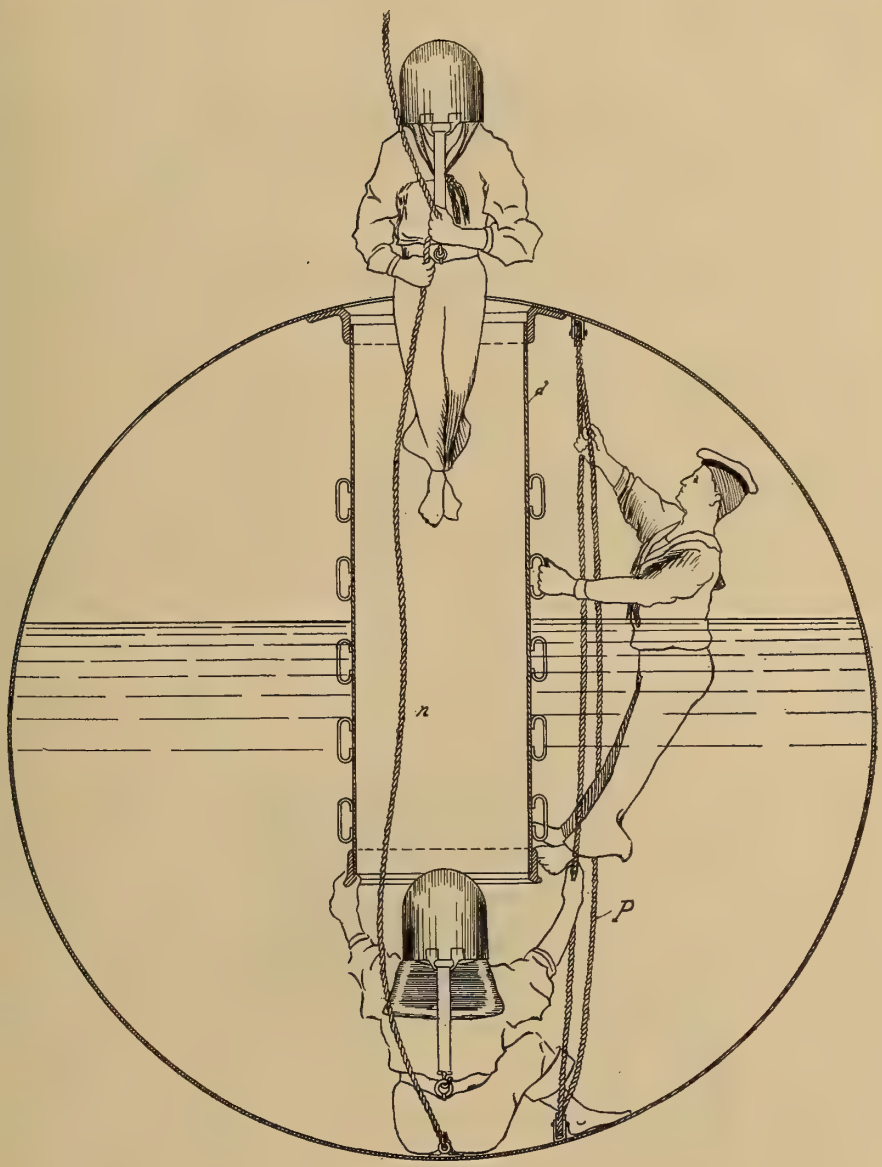
The plan which has been adopted includes the use of air-traps arranged along each side of the submarine, and the hope of their successful action is quite justified in case of a leak in the lower part of the vessel, in which case the water enters the vessel and compresses the air in the upper part until the pressure inside is equal to that outside, when it would be possible to open the hatch of the conning tower and thereby allow the water to rush in and fill all except the air-traps. The life-saving dresses are kept in these air-trapped passages, so that the men have in almost all cases sufficient time to retire to these traps and then don the dress, and after the hatch has been opened by one or two of the men so equipped the rest will, one by one, find their way to the exit, when the buoyancy of the helmet will quickly bring them to the surface. Strict discipline and absolute adherence to a system thoroughly practiced beforehand is the only hope of success, as all operations will probably have to be conducted in the dark and as communication by word of mouth would be impossible.

Should the vessel be holed in its upper portion, the danger is far greater, as the air will escape more readily through a hole in that portion and be replaced by water; therefore, there is less air to be compressed in the first instance, and the water will, consequently, rise to a higher level in the vessel before the operation of putting on the life-saving dress and the preliminaries of opening the hatch can be begun.

Unless special precautions have been taken to prevent the vessel from being holed within either of the air-traps, there might be the danger of one of these becoming useless, or one, or even both, might fail or become only partly useful by the submarine leaving its horizontal position, which might happen through a variety of causes. The C11, when sunk, was found to be lying at the bottom on her side. It seems, therefore, that, good as the present equipments might be, there are eventualities to be taken into consideration under which it would be essential to have additional means of security. To mention only one cause; the conning tower, which is as much or more exposed to danger than any other part of the vessel, might be so damaged by a collision that the opening of the hatch becomes impossible.

In making the following suggestions I am fully aware that the reserve of buoyancy in submarine boats is not great; but, nevertheless, there should be an additional means of escape provided for the crews of boats of the present type in case the boat is sunk, even if such means reduces the present reserve of buoyancy.

My first suggestion is shown by Fig. 1 of the accompanying drawings; *a* is the hull of the boat, in the top of which is an aperture about



MEN RISING THROUGH CYLINDER SHOWN IN FIG. 2.

1 foot 6 inches diameter, which is normally closed by a cover *b* which is fitted water-tight into the angle-iron ring *c*. A cylinder *d* is riveted to the ring *c*, the cylinder being long enough to contain a man standing on the foot rest *e*. To the bottom of the cylinder is fitted a valve *f*, normally held up by a suitable catch; *g* is a light metal dome or helmet secured to *b*. Inside *b* is a staple to receive a hook at one end of the rod *i*, the lower end of which passes through the bridged retaining piece *j*, which fits on the bottom of the cylinder, the top cover being held firmly by the nuts *k* · *k*. When it is necessary to send a man to the sur-

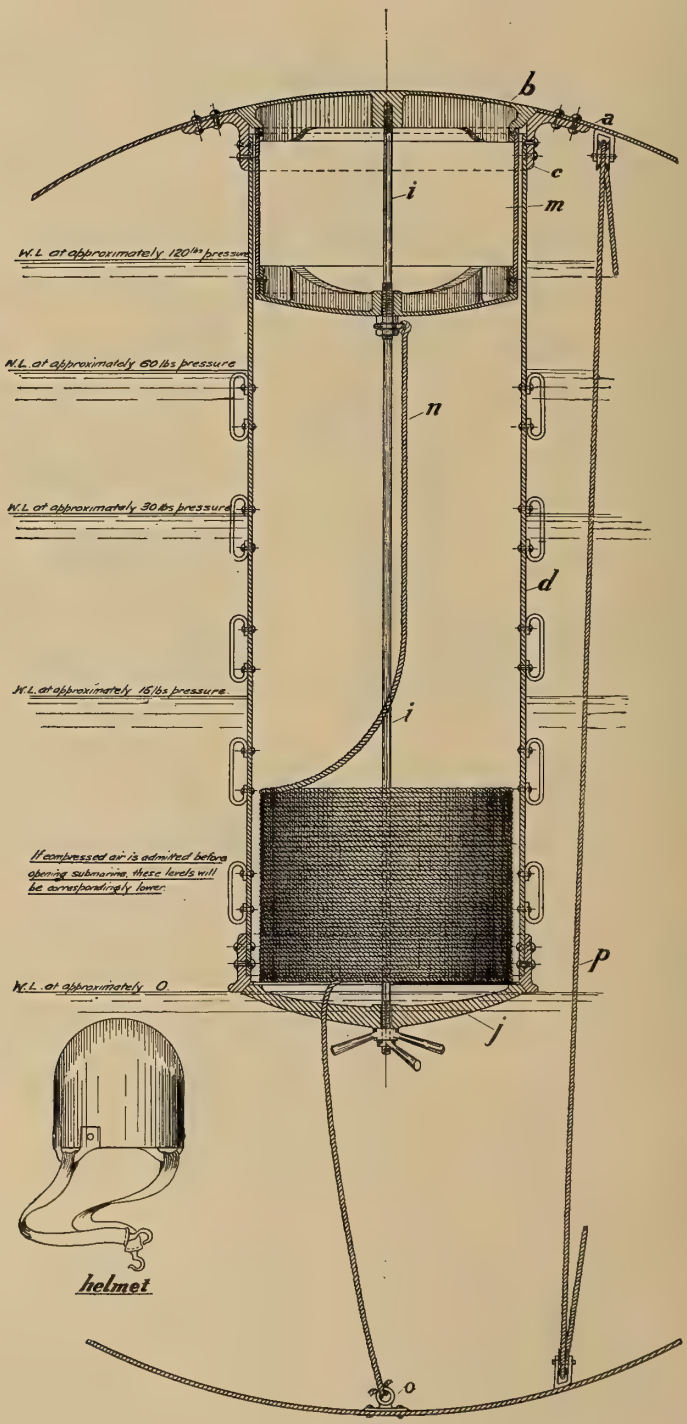


FIG. 2.—CYLINDER AND ROPE ARRANGEMENT FOR THE ESCAPE OF THE CREW

face the bridged retaining piece *j* is removed, and the man, after unhooking the rod *i*, climbs into the cylinder *d*, and, standing on the foot rest *e*, he lets down the valve *f*, thus closing the bottom end of the cylinder, Then grasping one of the handles *h*, he opens the valve *l* and allows the water from the sea to enter the cylinder till the cover *b* is free to leave its seat and the dome *g* and the man clinging to the inside of it rises to the surface. The dome *g* is long enough to cover the head and chest of the man; but this dome can be modified, or dispensed with, where other diving helmets are in use. As this means of escape can only be used once, it will be necessary to provide as many of these outlets as there are members of the crew, or to make each cylinder large enough to take three men at once; or, as shown in Fig. 2, the cylinder *d* may have a rope *n* coiled down in it long enough to enable the buoy to rise to the surface, say 30 or 40 fathoms. One end of the rope is secured to the buoy *m* and the other to a ring *o* at the bottom of the boat. When the crew of a sunken boat have to escape, the bridged retaining piece *j* is removed and sea-water admitted into the boat till the buoy rises to the surface. The air in the boat will be compressed by the water, which will rise to about the levels marked on Fig. 2 under different submersions. The crew inside the submarine will be able to tell by the instruments in how many fathoms of water they are lying, or, if in the dark, they will be able to judge by the height to which the water rises, and if submerged in more than, say, 25 fathoms, compressed air should be admitted into the interior of the boat, so as to prevent the water from rising too high. As the buoy rises, it uncoils the rope *n* and carries one end with it to the surface, thus indicating the position of the wreck and affording a guide and support for the escaping crew. The outside of the cylinder is provided with handles, to serve as guides to enable the men to pull themselves down while being hampered by the wearing of the helmets and the water; *p* is a guide rope for a similar purpose, by means of which the men can assist each other to overcome the buoyancy of the man wearing the helmet or suit. Each man of the crew before lowering himself would put on a dome or helmet, as before, but rather smaller, so as to reduce the buoyancy, or, better still, one of the life-saving dresses already described.

In order to retain the utility of this suggestion, even if the sunken submarine is not lying the right way up, three or four tubes, as shown in Fig. 2, could be installed, each in a different direction, so that whichever way the boat lies one of the tubes would always be upright, or nearly so. The next suggestion is probably impracticable, but would answer the same purpose with a lesser expenditure of space.

As shown by Fig. 3, the cylinder *d* is not riveted to the hull, but is capable of being secured to one of a series of manholes disposed round the hull of the boat, so that in case of a wreck where the boat should turn on her side or bottom upwards, the crew would still be able to escape. In this case the manholes are each provided with an outside valve cover *b*; *r* is a casting of the type of a sluice with a slide valve *s*, which can be closed or opened at will from inside the boat. When the crew have to leave the vessel the inside cover is removed; the casting *r* is secured to the manhole frame by the swivel bolts and wing nuts. The cylinder *d* is then bolted to the casting *r*. When the cylinder is in position, a dome or helmet is placed in it and held up by the spring catch *x*. One of the crew then opens the sea-water valve *w* and admits water from the sea above the slide *s*. To dislodge the cover *b*, a little extra pressure from a hand force pump will be necessary. A man then gets into the cylinder and closes the valve *f*. Water is then admitted from the valve *v* to the under side of the slide

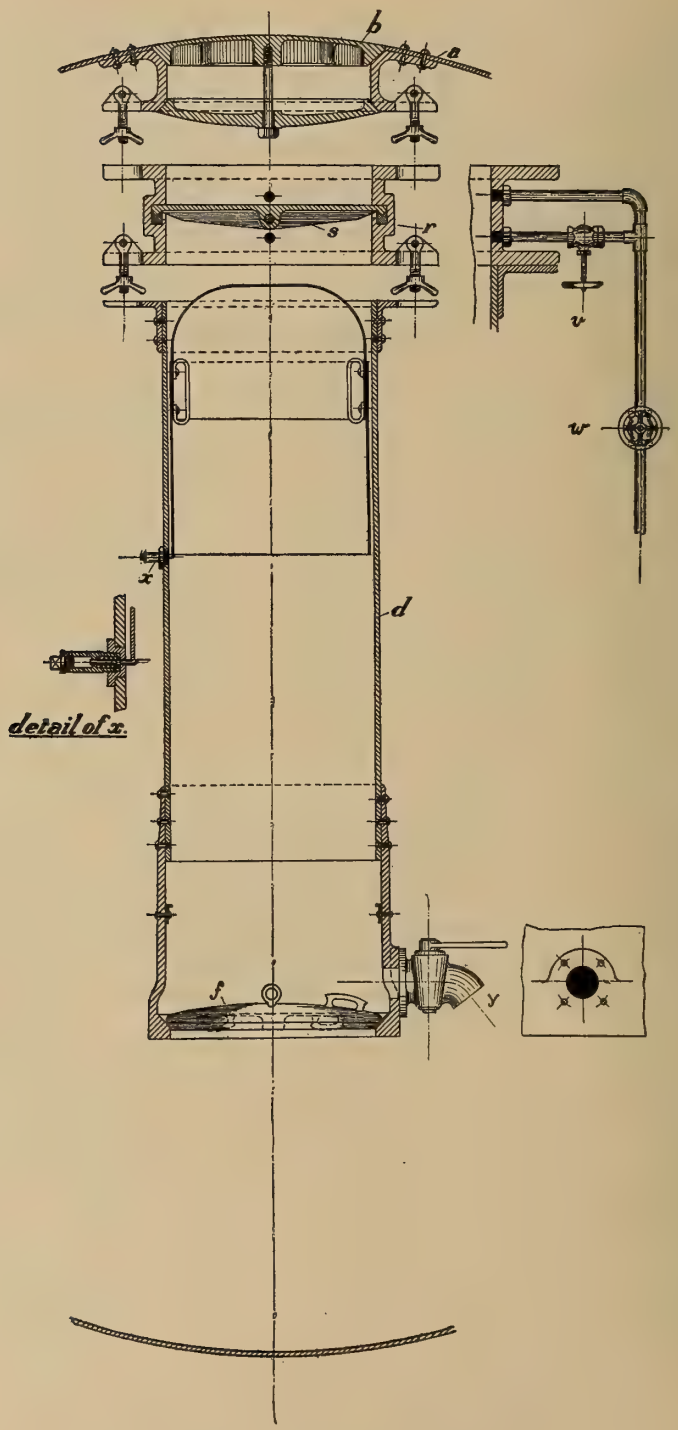


FIG. 3.—CYLINDER TO BE SECURED TO THE MANHOLES

valve *s*. When the pressure on the under side of the valve *s* is equal to the pressure outside, the valve, being balanced, is opened by the crew, the men rising to the surface as before in the case of Fig. 1. The slide *s* is then closed, the cock *y* is opened, and the cylinder emptied of water. Another man then enters the cylinder and the same operations are repeated till all but one of the crew has left. In order to allow the last man to escape, an additional apparatus, like that in Fig. 1, should be used for this man.

The plans are not intended to serve as working drawings, but only to illustrate an idea which must, if accepted, be adapted to the existing arrangements and the vacant space in submarines.

In conclusion, I would ask the indulgence of experts, if in their opinion these suggestions should be of little or no use, being solely prompted by humanity and a desire to reduce in future as much as possible the already heavy list of casualties.

THE DEVELOPMENT OF STEAM NAVIGATION ON THE GREAT LAKES

By James Cooke Mills

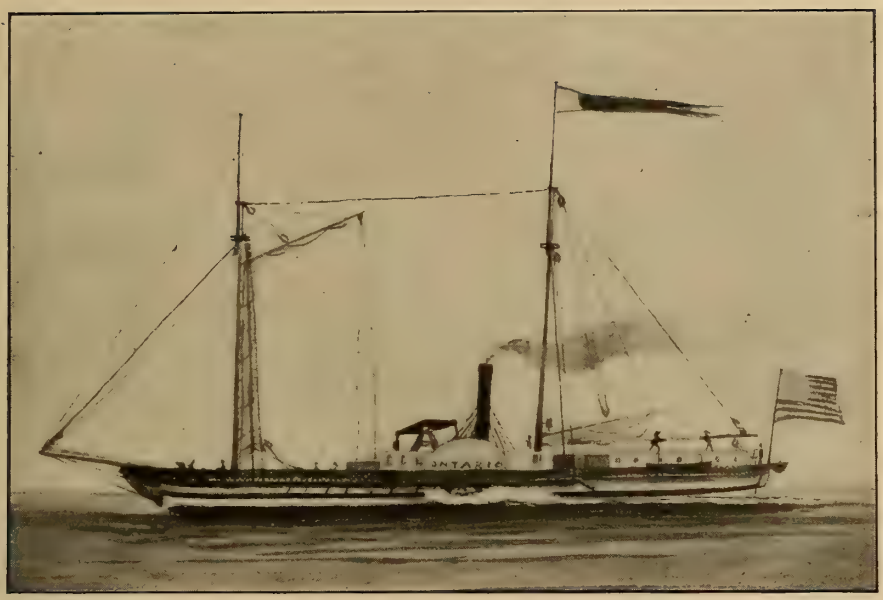
It is well known that the largest portion of the water-borne commerce of the United States is conducted on that magnificent series of inland fresh-water seas known as the Great Lakes. In connection with the present interest in the development of steam navigation it is believed that an account of the beginning of this great transportation system may well be placed on record, and that the story of the first steamboat whose successors represent the latest type of modern navigation shall be given in connected form from the chronicles of the time.—The Editor.

SOMEWHERE back in the remote realms of Indian tradition and long before the advent of the "pale faces" on the soil of America, the birch-bark canoe, so skillfully made and deftly handled by the aborigines, had its beginning, its baptism, in the clear blue waters of the inland seas. For centuries, and until the pioneer fur traders had pushed their way beyond Michilimackinac to Green Bay, the Indian canoe was the only means of conveyance on the lakes and rivers. It served well the purposes of its creation, and was extensively used in the fur trade, often being laden with as much as three tons of the valuable cargo in a trip from the trading stations on the upper lakes to the Niagara frontier.

The early French explorers evolved the bateau, and later the Mackinac boat, and, being built entirely of wood, they proved much stronger and more seaworthy craft. The barge followed, and was towed or poled along the shores and through the streams by the force of human strength. Then came the sailing vessel, which, in the history of all civilized nations, is the child of antiquity, as "it formed the primitive cradle of the human race." It relies, however, entirely upon its good genius, that mysterious and invisible force which comes from on high.

Steamboats belong exclusively to modern times, and represent progress, speculation and haste. Man is the god of the steamer; it depends on him for its every movement, and without him it is a helpless hulk upon the waste of waters. The inland seas knew not the churn of paddle-wheels, nor did the Indians along their shores have their first sight of the "big canoes belching fire and smoke" until about ten years after Robert Fulton had given the world the first successful steamboat. During the first decade following this most important event in navigation steamers had been introduced upon the waters of the larger Western rivers. They were modeled very closely after the early Fulton steamboats, and it is probable that their engines were of the Watt design and, with their boilers, were brought over from England. The settlements along the chain of Great Lakes and the connecting rivers had not then developed the population to furnish sufficient traffic for boats propelled by steam; and, furthermore, the craft then in service on the Hudson and other rivers were designed and built only for quiet and smooth waters. Upon waters subject to wave and swell the steamboat was still an untried experiment.

In 1816 and the following year two large and staunch vessels on Lake Ontario were fitted out with steam power. But the action of waves and the rolling motion of swells were so little understood by the mechanics of the West that grave defects in the installation of the machinery nearly resulted in wrecking the vessels. They were not per-



STEAMBOAT "ONTARIO," THE PIONEER STEAMBOAT ON THE GREAT LAKES. BUILT BY ASHAEL ROBERTS AT SACKETT HARBOR IN 1816

fected and rendered seaworthy until some time later.

The first steamboat to ply regularly between ports on the Great Lakes as a mechanical and commercial success to the extent of paying dividends to its owners was the *Walk-in-the-Water*. This singular name was suggested by an incident related by an old navigator of the lakes. "When Fulton first steamed his boat, the *Clermont,* up the Hudson in 1807, an Indian standing on the river bank, gazing long and silently at the boat moving upstream without sails, finally exclaimed: 'Walks-in-water!' The man of the forest saw the boat stemming the current, unaided by any power known to him. He observed the paddle-wheels revolving slowly, and intuitively comprehended that when a paddle struck the water there was a step forward." The name *Walk-in-the-Water,* however, being so long, was not generally used either in conversation or print. Being the only boat of her class on Lake Erie, where she plied regularly, she was usually designated as "The Steamboat."

This historic vessel, which well earned the title of pioneer steamboat on the Great Lakes, was built early in 1818 at the mouth of Scajaguada creek, in the village of Black Rock. At that time and for several years previous Nathaniel Sill and two or three others had warehouses at Black Rock, situated nearly opposite the head of Squaw Island; and just below them was the shipyard which had seen the birth of many of the lake sailing craft. Excepting the few buildings and the surrounding clearings near the river bank, all the land in the vicinity of Black Rock was covered with native forest. A large proportion of the timber was white oak, which, as is well known, was the principal timber used in shipbuilding. This timber land extended over the greater part of what is now the city of Buffalo.

The keel of the vessel was laid by Noah Brown, who had built several of the steamboats running from New York, and the construction was according to plans by Fulton, and followed very closely the dimensions of the steamer bearing his name, which

had been built five years before. The *Walk-in-the-Water* was launched on May 28, 1818, and was 135 feet length of deck, 32 feet breadth and 8 feet 6 inches depth of hull, registering 338 gross tons. She had two masts, carrying mainsail, foresail and fore topmast staysail, which were always used when the wind was favourable. Her paddle-wheels were placed exactly amidships, and the machinery was below the deck. The boiler was forward of the wheels, and measured 20 feet long by 9 feet in diameter, while the long smokestack pointed upward rakishly, the whole effect causing a native Frenchman, upon seeing the vessel for the first time, to exclaim: "Jean, Jean, just see what are these Yankees a-sending us now but a sawmill!"

Of the engines of the *Walk-in-the-Water,* no records, such as diagrams or descriptions, are extant. It is reasonable, however, to suppose that, since the hull was constructed so closely after the designs of the *Fulton,* the machinery was very much of the same type as aided in that vessel's success in New York waters. Full description and diagrams of these engines were given in an article on the *Fulton* appearing in the number of this magazine for April, 1907. It is an historical fact that the engines of the *Walk-in-the-Water* were in constant use during the navigation season for more than twenty years, having been installed in two successive hulls following the wreck of the pioneer.

The *Walk-in-the-Water* was completed about the middle of August, her license and enrollment bearing the date of August 22, 1818. Her owners, being mostly residents of New York, evidently were reluctant to trust their vessel to the navigation of fresh-water skippers, for they brought from the Hudson Capt. Job Fish to command. He had been an engineer for Fulton, Livingston and Co., and was known to be a careful and experienced sailor. The first pilot was John Davis, a Lake sailor, who was afterward made captain. Everything being in readiness, the vessel cast loose from the natural rock wharf which gave Black Rock its name early in the afternoon of

THE "FRONTENAC," THE PIONEER BRITISH STEAMBOAT ON THE GREAT LAKES, BUILT AT KINGSTON, ONTARIO, 1816

THE RIVER FRONT OF DETROIT IN 1820, SHOWING THE STEAMBOAT "WALK-IN-THE-WATER
(From an old print)

the 23d, and started on her maiden trip up the Niagara River. The current of the river was very strong, almost attaining the force of rapids, and the little steamboat, her wheels churning the water into foam, could make no progress against it. Her twenty-nine passengers were beginning to wonder how the vessel was ever to reach the open waters of Lake Erie, only a few miles away, when they witnessed the application of a decidedly novel and unique power to help them on their way. Captain Fish managed to send a line ashore supported by two skiffs, the shore end of which was hitched to a yoke of oxen, and by their efforts the vessel slowly ascended the river to the lake.

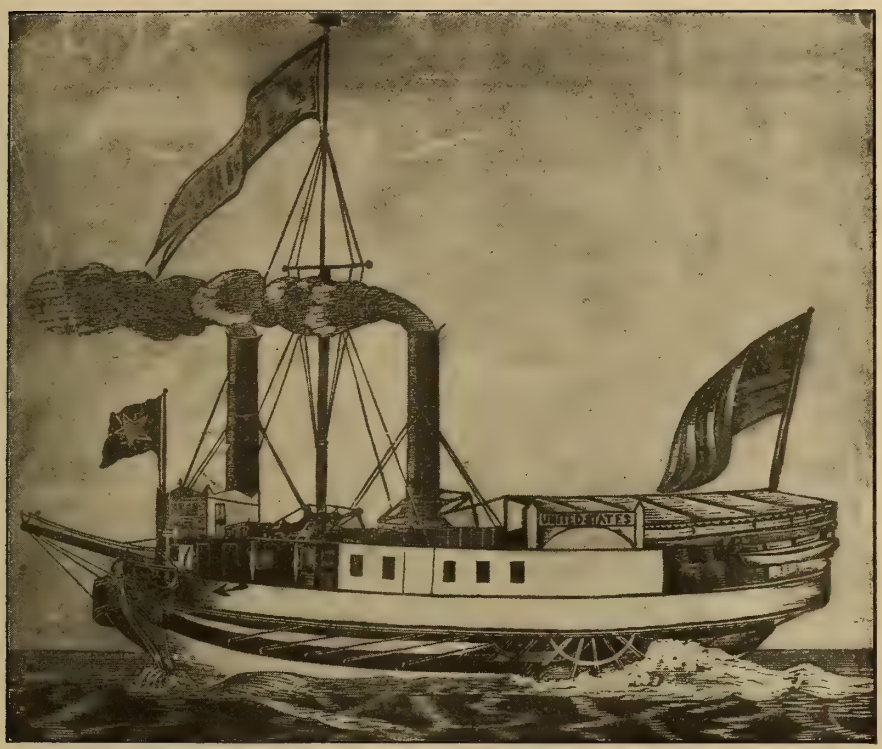
To the hundreds of inhabitants lined on the shore to witness the departure of the first steamboat to ply Lake Erie the scene must have been novel and picturesque. Only a little way from the bank, the marine pride of the West was struggling with the swift current, her paddle-wheels revolving to their utmost speed, while her engine puffed and fumed, and great clouds of dense smoke and red-hot cinders poured from her stack. On the beach the yoke of oxen tugged steadily at the end of the long tow line, the combined efforts of beast and steam proving sufficient to move the vessel forward. This was the historical "horned breeze" on the Niagara River, brought into use when the current was stronger than the applied steam power.

An important article of equipment on the steamboat was a small cannon, a four-pounder, mounted on wheels and securely fastened on the forward deck. Steam whistles had not been brought into use in those days, and the cannon was fired before leaving as a warning that she would depart in a half-hour. On arrival off a village it was fired a mile away to let people know she was coming. The third or fourth season after the steamboat was put in service, during a gale, the fastenings of the cannon became loosened and it was lost overboard. On all the chain of lakes there were no harbours other than formed by nature at this time, and no docks or landings had been built on Lake Erie. The *Walk-in-the-Water* would run as close to shore as the depth of water would permit and anchor, sending the passengers

and goods ashore in a small boat. Upon running on the beach sailors took the women and children on their backs and waded through the surf to dry ground. If the weather was stormy or the lake too rough for making safe landings, the passengers and goods were often taken on to the end of the route and brought back and landed on the return trip.

On her first trip the *Walk-in-the-Water* stopped at Dunkirk and Erie, and arrived off Cleveland about noon of the following day. Of this important event the account of an eye-witness is interesting as showing the incredulous attitude of the people toward a vessel propelled by power of man's creation. He relates: "On the 24th of August, 1818, an entire novelty—the like of which not one in five hundred of the inhabitants had ever seen—presented itself before the people of Cuyahoga county. On that day the residents along the lake shore of Euclid saw upon the lake a curious kind of vessel, making what was considered very rapid progress westward, without the aid of sails, while from a pipe near its middle rolled forth a dark cloud of smoke, which trailed its gloomy length far into the rear of the swift-gliding, mysterious traveler over the deep. They watched its westward course until it turned its prow toward the harbour of Cleveland, and then returned to their labours. Many of them doubtless knew what it was, but some shook their heads in sad surmise as to whether some evil powers were not at work in producing such a strange phenomenon as that on the bosom of their beloved Lake Erie. Meanwhile, the citizens of Cleveland, perceiving the approach of the monster, hastened to the lake shore to examine it. 'What is it? What is it? Where did it come from? What makes it go?' queried one and another of the excited throng. 'It's the steamboat! it's the steamboat! that's what it is!' cried others in reply. 'Yes! yes! it's the steamboat!' was the general shout; and with ringing cheers the people welcomed the first vessel propelled by steam which had ever traversed the waters of Lake Erie. * * * The steamboat was of about 338 tons capacity, and could

THE LOSS OF THE "WALK-IN-THE-WATER"
(From a sketch in the possession of Mr. C. M. Burton, of Detroit)



STEAMBOAT "UNITED STATES," BUILT AT OGDENSBURG, N. Y., IN 1831
(From an old woodcut made by Captain James Van Cleve in 1834)

carry 100 cabin passengers and a still greater number in the steerage. Its best speed was 8 to 10 miles an hour, and this was considered wonderful. All Cleveland swarmed on board to examine the new craft, and many leading citizens took passage in it to Detroit, for which place it soon set forth."

Proceeding westward, the steamboat shortly after midnight arrived off Sandusky Bay, where she anchored until morning, and then entered the bay and took on a load of wood. She then turned her prow northward by west, steaming among the islands of Lake Erie en route to the mouth of Detroit River. The welcome given the steamboat at Detroit and the account of the entire trip from Buffalo was graphically narrated in the Detroit *Gazette,* of August 26, 1818:

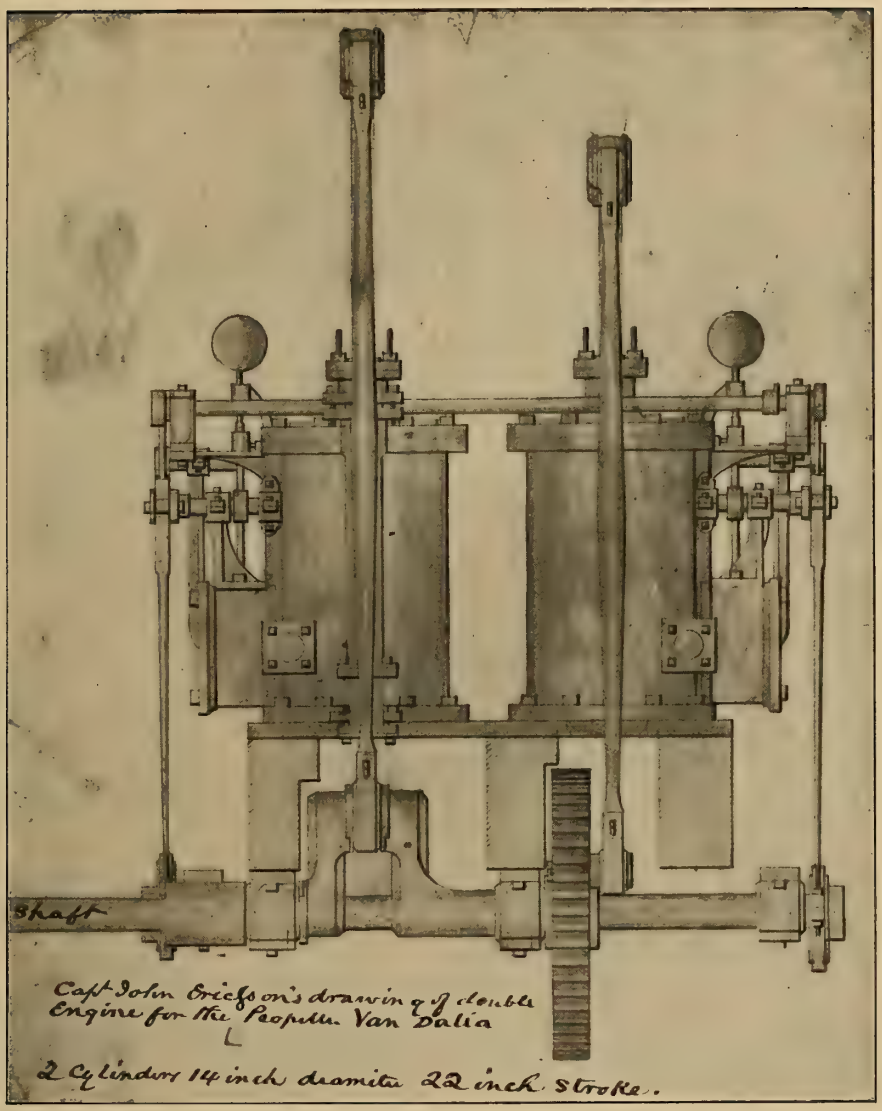
"Yesterday, between the hours of 10 and 11 A. M., the elegant steamboat, *Walk-in-the-Water,* Capt. Job Fish, arrived. As she passed the public wharf and that owned by Mr. J. S. Roby, she was cheered by hundreds of the inhabitants who had collected to witness this (in these waters) truly novel and grand spectacle. She came to at Wing's wharf. She left Buffalo at half-past one o'clock on the 23d, and arrived off Dunkirk at thirty-five minutes past six o'clock on the same day. On the next morning she arrived at Erie, Capt. Fish having reduced her steam during the night in order not to pass that place, where she took on a supply of wood. At half-past seven A. M. she left Erie, and came to off Cleveland at about eleven o'clock. At twenty minutes past six in the evening of the same day she steamed from off Cleveland and arrived off Sandusky Bay at one o'clock in the morning, where she anchored until

daybreak, when she proceeded up the bay to Venice to wood. She left Venice at 3 o'clock P. M., arriving at the mouth of Detroit River at nightfall, where she anchored until morning, the whole time employed in sailing in this first voyage from Buffalo to this place being 44 hours and 10 minutes, the wind being ahead during the whole passage. through the lakes by sturgeon. Of the truth of the report they are now perfectly satisfied. The cabins of this boat are fitted up in a neat, convenient and elegant style; and the manner in which she is found does honor to her proprietors and her commander. A passage between this place and Buffalo is not now merely tolerable, but truly pleasant. To-day

THE "VANDALIA," THE FIRST SCREW PROPELLER STEAMBOAT ON THE GREAT LAKES, 1841
(From an original water-color drawing by Captain James Van Cleave)

Not the slightest accident happened during the voyage, and all the machinery worked admirably. Nothing could exceed the surprise of the sons of the forest on seeing the *Walk-in-the-Water* moving majestically and rapidly against a strong current without assistance of sails or oars. They lined the banks near Malden, and expressed their astonishment by repeated shouts of 'Tai-yoh-nichee.' A report had been circulated among them that a big canoe would soon come from the 'noisy waters,' which, by order of the Great Father of the Cho-mo-ko-mous, would be drawn she will make a trip to Lake St. Clair with a large party of ladies and gentlemen. She will leave for Buffalo to-morrow, and may be expected to visit us again next week."

During her stay at Detroit the *Walk-in-the-Water* was the wonder of all, and she was visited by many people, some of whom traveled from beyond the little settlement to see this marvelous craft. Among the curious ones were quite a number of Indians, who manifested great astonishment and awe. In their way, they wanted to see and examine everything, and while they were very in-


Shaft
Capt John Ericsson's drawing of double Engine for the Propeller Van Dalia
2 Cylinders 14 inch diameter 22 inch Stroke.

SIDE VIEW OF THE ENGINES OF THE STEAMER "VANDALIA," THE FIRST SCREW STEAMSHIP ON THE GREAT LAKES, 1841

(From the original drawing by Captain John Ericsson, now in the possession of Mr. Frank Kirby, of Detroit)

tently engaged in examining the engine, which they seemed to understand "fulled" the boat along, the huge boiler and paddle-wheels, the engineer, Mr. Calhoun, lifted the safety lever, letting off steam under its greatest pressure at the time. The Indians started with a spring, leap and bound off and away from the boat, and ran up the hill through the village, nor did they lessen their speed until they were out of sight of the white man's "big canoe." For a long time after no Indian could be induced to approach nearer the hissing monster than the top of the hill.

From an old advertisement of the steamboat published in the Niagara

STEAMER "ONTARIO," REPRESENTING AN INTERMEDIATE TYPE, BUILT AT CLAYTON, N. Y., IN 1847

Patriot, of September 15, 1818, some interesting facts of operations are obtained. In this curious sheet the sailings are announced as to take place "on the 15th and 26th of September; the 7th, 17th and 27th of October, and the 6th and 16th of November, at 4 o'clock P. M. Returning, she will leave Detroit on the 21st of September; the 2d, 12th and 22d of October, and the 1st and 11th of November, at 4 P. M." This shows that the round trip required about ten days, although the actual time of the steamboat while under way during the single passage between the two places averaged about 42 hours, more time being spent at anchor, making landings, taking on wood and lying at the wharfs at the terminal points. The distance covered in a single passage was about 320 miles, giving an average speed of nearly 7½ miles an hour.

The fuel used in the boiler of the *Walk-in-the-Water* was entirely of bass, pine and hemlock, all split fine and well seasoned. Hardwood did not seem to answer so well, as that which would give a more lively and intense fire was needed. Bituminous coal had not then been brought into use on the frontier, and it would not have been used on the steamboat in any case. The wood, delivered at the dock or landing place, cost $1.25 to $1.75 a cord, and the farmers along the lake shore near the stopping places of the vessel found it quite to their advantage to secure the contract for supplying wood for "the steamboat." Many of them had quantities of fuel timber well seasoned for sale a,s they were clearing off their lands in preparation for cultivation.

The rates of fare early established by the steamboat, including accommodations and meals, seem very high in comparison with the rates of today, and were:

"From Black Rock and Buffalo to Dunkirk, cabin, $3; steerage, $1.50.

"From Black Rock and Buffalo to Erie, cabin, $6; steerage, $1.50.

"From Black Rock and Buffalo to Grand River, cabin, $10; steerage, $4.

"From Black Rock and Buffalo to Cleveland, cabin, $12; steerage, $5.

"From Black Rock and Buffalo to Sandusky, cabin, $15; steerage, $5.50.

"From Black Rock and Buffalo to Detroit, cabin, $18; steerage, $7.

"Waiters, half price of cabin passengers. A cabin is fitted up for the accommodation of families, who, with their baggage, will be carried at very low rates."

These rates were afterward reduced to $15, and again to $12, from Buffalo to Detroit, and proportionately between intermediate points.

The *Walk-in-the-Water,* during her short career, never entered the stream at Buffalo, for the very good reason that no harbour existed there the waters of which would have floated her. During the passages of the year 1818 it was the practice of the steamboat to haul to opposite Buffalo to take on and deliver passengers and baggage. When she started the navigation season of 1819, when passing Buffalo creek, a yawl came out and the passengers hailed her. They were answered, as she steamed steadily on her way, with: "Gentlemen, you must distinctly understand that the port from which we sail is Black Rock." So the passengers were obliged to return to the little village of Buffalo, and they secured accommodations on a sailing vessel at anchor in the bay, or waited until the next trip of the steamboat, ten days afterward, and then they went aboard at the dock at Black Rock. The most intense rivalry existed between the two villages for supremacy, and, after many struggles for a decided advantage, the turning point in favour of Buffalo, and which made it a port and a place of commercial importance, was the building of another steamboat—the successor of the *Walk-in-the-Water.*

"The steamboat" had continued in service during the seasons of 1819, 1820 and 1821, earning a handsome profit for her owners, when her short history was brought to an end by wreck on November 1, 1821. She had left her dock at Black Rock on her regular trip at 4 o'clock, and upon reaching the lake encountered threatening weather. Continuing on her course for a few miles into the open waters of the lake, the rising storm compelled her captain to anchor near the shore. Toward morning the storm increased to a gale, which tore the vessel loose from her anchorage, and she was driven rapidly and helplessly on the shore. She struck the light, sandy beach just above the old lighthouse, and nearly opposite the foot of Main street, Buffalo. She was driven so high on the shore that the engineer, Mr. Calhoun, jumped overboard, waded to the land, and started for the village to give the alarm, the catastrophe being hidden from the sight of the villagers by the forest along the shore.

STEAMER "CITY OF TORONTO," BUILT AT NIAGARA, CANADA, IN 1861

General Lucius Storrs, Capt. Benjamin Caryl, keepers of the Mansion House, and others quickly responded, and soon were on their way across the creek and hastening through the woods to the stranded steamboat. Aided by the efforts of Capt. Rogers, Pilot Wm. T. Miller and the crew, the rescuers stretched a line from the vessel to the shore, along which a small boat was guided back and forth, thus landing all the passengers safely. They were taken to the Mansion House, given dry clothing, and otherwise made as comfortable as shipwrecked people could well be.

The stranded vessel did not at

STEAMER "ADMIRAL," AN OLD UNITED STATES REVENUE CUTTER

once go to pieces, and the baggage and goods were saved during the day and taken to Buffalo. When the gale had subsided and the waters of Lake Erie had resumed their normal level, the wrecked hulk was found to be high and dry on the beach. An examination of the machinery showed the engine and boiler to be but little damaged. The mass of broken wood and twisted iron had hardly settled in the sands ere it was proposed to build another steamboat, and Noah Brown came from New York to make a contract for the work. The engine, boiler and machinery were recovered from the wreck in good condition for use in the new vessel built during the winter of 1821-2.

At this juncture a great controversy arose between the citizens of Black Rock and Buffalo as to the place where the new steamboat should be built, and it grew very bitter. For ten years previous Black Rock had been the principal port at the east end of Lake Erie, Buffalo at the time being of less importance, as the outlet or channel of Buffalo creek afforded only sufficient water for flat boats, and after a heavy blow there was not even that depth. The people of Black Rock declared that if the vessel were built in the shallow creek it would rot before it floated on the waters of Lake Erie. Both places agreed to furnish all timber to go in the vessel at very low prices, and made other concessions; but in the end Buffalo prevailed by giving, in addition, bonds for a large amount, guaranteeing that the channel of the creek would be deepened by a certain time, so that the new steamboat, when built, could be floated out into the lake. As a penalty, the owners were to be paid $150 for each day it should be detained after completion ready for the lake service.

The deepening of the channel of Buffalo creek was a great undertaking for the people in those times; but, after heroic efforts, the task was accomplished within the specified time, to the great joy of all the inhabitants, many of whom had contributed manual labour to the project without pay or recompense. Without the aid of excavating machinery, for such means were then unknown, the people devised crude scrapers, and by great labour removed the

THE "CITY OF CLEVELAND," A MODERN LAKE STEAMSHIP

sand from the old waterway. First piles were driven along both edges of the channel by means of a "driver" extemporized from an old mortar. A scraper was made of a log sawed in half lengthwise and armed at the edge thus left with long saw blades. This crude and unwieldly device was floated into place by a scow and dropped to the bottom. It was then dragged out by oxen, bringing with it a small quantity of sand and silt. Judge Samuel Wilkeson was a leader of this project, and "his good works in creating Buffalo City were examples of energy, ingenuity and persevering sacrifice."

A MODERN LAKE PASSENGER STEAMER, THE "COLUMBIA"

THE "SAINTE MARIE," A MODERN ICE BREAKER ON THE GREAT LAKES

The second steamboat on Lake Erie, the *Superior,* was built on the bank of Buffalo creek at the foot of Washington street, and was launched on April 16, 1822. She was of widely different proportions than the *Walk-in-the-Water,* and although registering about the same tonnage, was 126 feet length of deck, 21 feet breadth and 10 feet 6 inches depth of hull. A streak was cut through the woods and a road built to haul the boiler and machinery of the wrecked vessel to the new hull, and it was installed in about the same position as originally placed in the *Walk-in-the Water.*. When completed, the *Superior* steamed out of the narrow

LAUNCH OF THE STEAMER "HUDSON," SHOWING THE SIDE LAUNCHING SYSTEM GENERAL ON THE LAKES

THE "TASHMOO," A FAST PASSENGER BOAT ON THE LAKES

creek, and, with some difficulty, reached the open water of the harbour.

The *Superior* left Black Rock on her first trip for Detroit on April 23, 1822; but for some reason passed by Buffalo creek, as the precursor of steam navigation on the Great Lakes had done. After her third trip, on or about June 1, and ever after, the *Superior* made Buffalo her stopping place. From this time Buffalo began to assume a superiority over Black Rock, in a commercial way; and the further deepening of the channel leading to the deep water of the lake to accommodate all vessels of the period, together with the location of the western terminal of the then building Erie Canal, seemed to settle the controversy between the rival villages, and Buffalo began to be a place of importance. Very soon merchants and others who had expected Black Rock to become the metropolis of the western lake country moved to Buffalo, and Black Rock was soon only a dot on the map.

In 1824-5 a sister-ship of the *Superior* was built and named *Henry Clay,* and during the season of 1825 the two steamboats maintained a four-day service between the ports of Lake Erie and Detroit. The *Superior* continued the service for some years, even after many larger and finer steamboats had been built and run in opposition. She was finally converted into a sailing vessel in 1835, and the engines and machinery, which had seen service in two hulls, were placed in a new vessel named the *Charles Townsend.* The *Superior* was lost in a gale in 1843.

After 1825 the growth and development of steam navigation on the Great Lakes was very rapid, and in a few years had attained large proportions.

THE EFFICIENCY OF HEAT DRYERS

By W. B. Ruggles

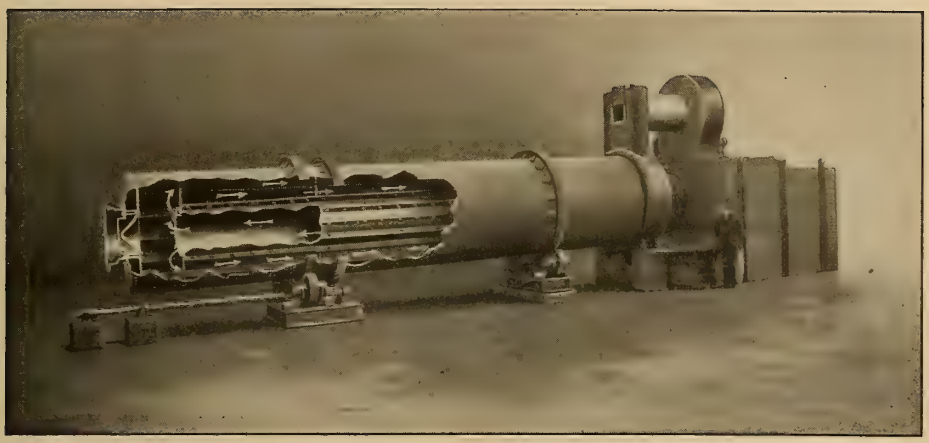
TO determine the total efficiency of a dryer using direct heat is a simple matter, but to discover where the losses occur is not so easy. There are four ways in which losses may occur—in unconsumed carbon, due to imperfect combustion; in heat carried out by the exhaust gases; in unnecessary heat carried away by the dried material, and in radiation from the furnace and shell.

The first of these is generally ignored, this loss being charged against radiation. Recent tests, however, have shown it to be a considerable factor, unless a large combustion chamber is supplied, in which space and time are given for the perfect combination of oxygen with the carbon monoxide. When the dryer is so arranged that the flames impinge directly upon a cascade of cold and wet material they are quenched suddenly and a considerable amount of carbon passes off unconsumed. This, in certain types of machines, may amount to 7 or 8 per cent. of the value of the fuel.

The heat carried out by the exhaust gases is generally the largest item of the losses, and sometimes amounts to 30 per cent. or more. This occurs in dryers in which natural draught is relied upon to burn the fuel. As in a steam boiler, the temperature of the stack gases in such a dryer is seldom below 400 degrees F., and is often 600 degrees or more. It is easy to see that a dryer which utilizes, for instance, the 1,200 degrees between 1,300 degrees and 100 degrees is, other things being equal, about 50 per cent. more efficient than one utilizing only the 800 degrees between 1,300 degrees and 500 degrees. In order to get as much of the heat out of the gases as possible, it is necessary to use an exhaust fan and draw the gases against the flow of drying material, so that just before leaving the dryer it has been in contact with the cold and wet material. Undoubtedly some condensation occurs of the steam being carried out; but there is no ultimate loss, as the heat given up in condensation is absorbed by the material and aids in drying later in the process. When the current of the gases is reversed and flows in the same direction as the material, a temperature of at least 212 degrees F. must be had in the exhaust, so that no condensation may occur and moisture deposited upon the finished material.

The heat carried out with the dried material up to 212 degrees should not be charged against the efficiency of the dryer, as that temperature is necessary to the rapid drying of the material. All heat of the material above 212 degrees, however, is unnecessary in most operations, and, therefore, should be charged as a loss. This is generally not great, and is, in most cases, due to imperfect operation and not to the design of the machine.

Radiation varies greatly in different types of dryers. In some, the shell is cool enough to place the hand on without discomfort; in others, it

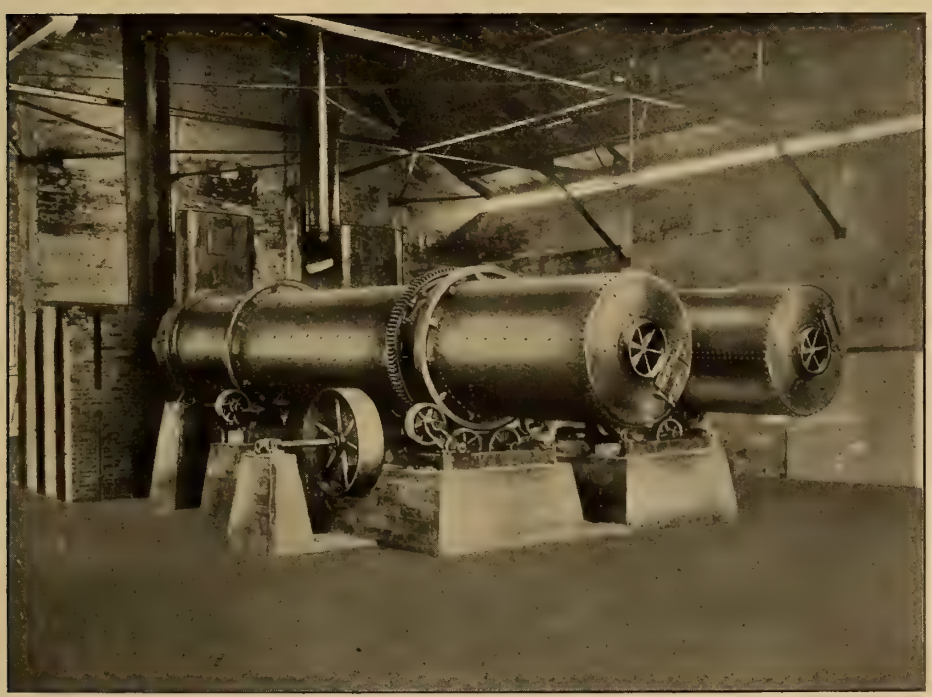


SECTIONAL VIEW OF ROTARY DRYER. RUGGLES-COLES COMPANY, NEW YORK

is not uncommon to see the shell red-hot for 10 or 12 feet from the furnace. This, of course, is in a single-shell type, in which the flames impinge directly upon the shell. The loss by radiation in such a dryer is very great. In a bricked-in machine the temperature is not so high; but, as more surface is exposed, the total loss is almost as great.

The amount of radiation cannot be determined directly by any test, and it is, for this reason, customary to determine the other losses and charge all the balance to this cause.

In order to illustrate the usual way



ROTARY DRYERS. RUGGLES-COLES COMPANY, NEW YORK

of making a dryer test, there is given below a case in which, to simplify it, the quantities are given in round numbers, but which follows very closely the actual conditions of a recent test. This shows a very high efficiency, as it was made on a dryer having almost perfect combustion, very low exhaust temperature, and in which the average temperature of furnace and shell was not over 150 degrees F. Tests on other types of dryers have shown efficiencies as low as 46 per cent. The coal used for fuel was dried and tested calorifically. The flue gases were measured by an aerometer and analyzed for CO, and the material tested for moisture and specific heat.

Amount of coal burned per hour..	400	lbs.
Amount of moisture in coal.....	10	per cent.
Calorific value of dry coal.....	13,000	B. T. U.
MATERIAL DRIED—BANK SAND.		
Amount of wet material per hour..	45,000	lbs.
Amount of dried material per hour.	42,750	lbs.
Specific heat of sand.....	.21	
Moisture in sand.....	5	per cent.
Temperature of air, sand and coal	60°	F.
Temperature of dry sand.....	224°	F.
Total moisture in coal.....	40	lbs.
Total heat per pound water 60° to steam.....	1,122	B. T. U.
Heat required to evaporate water in coal.....40 × 1122 =	44,880	B. T. U.
Total heat in dry coal 360×13000=	4,680,000	B. T. U.
Total heat for drying 4680000 — 44880 =	4,635,120	B. T. U.
Specific heat required to heat sand 60° to 212°...42750×.21×152=	1,364,580	B. T. U.
Total water in sand.....	2,250	lbs.
Total heat required to raise temperature of moisture and evaporate same.....2250 × 1122 =	2,524,500	B. T. U.
Theoretical heat required.....	3,889,080	B. T. U.
Efficiency of dryer.....$\frac{3889080}{4635120}$ =	85.8	per cent.
Total losses in dryer.....	14.2	per cent.
Excess temperature of sand.....	12°	
Loss by same...42750×.21×12=	117,730	B. T. U.
Percentage.....$\frac{117730}{4635120}$ =	2.5	per cent.
Quantity of air exhausted @ 100° per hour.....	450,000	cu. feet.
Weight of air exhausted @ 100° per hour.....	31,905	lbs.
Loss by excess temperature 100° — 60° =	40°	
Specific heat of air.....	0.2374	
Loss in exhaust air 31905 × 40 × .2374 =	302,960	B. T. U.
Percentage.....$\frac{302960}{4635120}$ =	6.5	per cent.
Amount of CO in exhaust gases per hour.....	3.4	lbs.
Value of CO as fuel, per lb.....	10,100	B. T. U.
Total loss.....10100 × 3.4 =	34,340	B. T. U.
Percentage.....$\frac{34340}{4635120}$ =	.7	per cent.

RECAPITULATION.

Loss by excess temperature of sand	2.5	per cent.
Loss by heat of exhaust gases.....	6.5	per cent.
Loss by imperfect combustion.....	.7	per cent.
Loss by radiation and other causes	4.5	per cent.
Dryer efficiency.....	85.8	per cent.
	100.0	per cent.

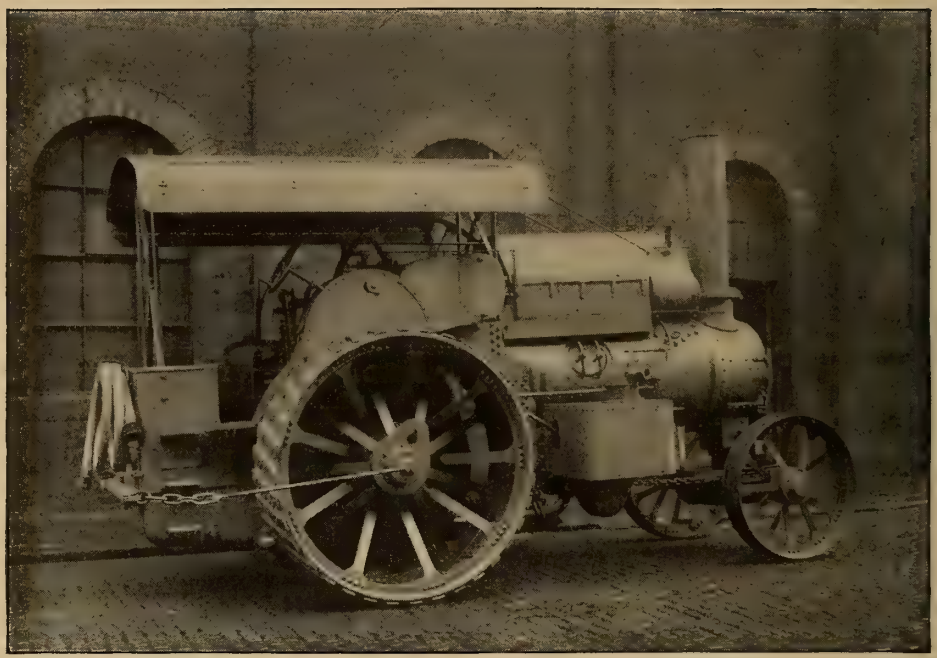
SPECIAL TYPES OF TRACTION ENGINES

By William Fletcher, M. I. M. E.

IN previous issues of CASSIER'S MAGAZINE the writer has contributed articles dealing with traction engines and tractors.* The present paper is concerned with special types, and will in no way touch upon or overlap the previous contributions. It is proposed in this article to illustrate and describe a number of traction engines and road locomotives specially built for foreign and colonial service, many of which are not even referred to in the firm's catalogues. The English traction engine has found its way into every country of the world, and few people realize the great number of purposes to which the modern traction engines are now employed beyond their chief work of hauling loads on the roads and for driving thrashing machines. In some instances a considerable amount of pioneer work was effected before the traction engine could be introduced into new districts. Want of fuel and water have often been barriers to progress, but suitable means for overcoming these difficulties have been devised by enterprising makers of traction engines. For instance, in Australia a traction engine had to make a 70 miles' journey across a waterless stretch of country. It was necessary for tanks of water to be carried on one of the wagons for the first half of the journey, a further supply being sent out to meet the engine to complete the distance. In some districts of South Africa huge tanks are fitted to the engine, sometimes carrying 500 gallons, and, in addition to this, a water-cart is hauled containing a further supply. A combined water lifter has been fitted to road locomotives, by means of which water can be drawn up from the river or other supply in the usual manner to replenish its own tanks; the apparatus can be used for raising water from the same source into the water-cart, effecting a saving of time and labour. The steam pumps mounted on some road locotives will serve the same purpose if fitted properly. Reference will be made to the steam pump in another connection further on. The writer saw a small traction engine hauling 10 tons of sand up a steep incline three miles in length; at the top of the incline no water was to be obtained, so a cask of water was carried in the wagon with the load. The total journey up and down the pass was about 10 miles. In this instance the engine was only fitted with one small tank; otherwise for this short distance the cask would not have been required. The work, however, was very severe for a small engine; the road was a rough one cut out of a mountain side, on the borders of Switzerland.

The fuel question is more acutely felt and not so easily overcome. In countries where the only supply of fuel is petroleum matters are easily arranged. Traction engines are often fitted with suitable apparatus for burning oil. The Holden system has been effectively applied to the burning of oil on traction engines where other fuel is not available. An oil tank occupies the place usually set apart for the coal; it may contain 60 to 100 gallons of fuel. In the firebox a fire-brick or ganister

* CASSIER'S MAGAZINE, June, 1896; January, 1909.



ROAD LOCOMOTIVE FOR COLONIAL SERVICE. MESSRS. FOWLER & CO., LEEDS

arch is constructed; the bottom of the firebox and the ash pan are lined with ganister. The burner in this instance is placed low down beneath the firebox frame; in some cases it is placed just below the hind axle, a ferrule passing through the water space for the ejector to point through into the firebox. All the pipes for fuel supply, steam jet, with regulating cocks, are included, the steam for working being taken from the steam chest or other place where a supply of dry steam can be obtained. A copper warming coil is fitted in the oil tank. The steam pipe for supplying this is arranged in a convenient manner. In some cases a semi-rotary pump is fitted on the tender side, with suction and delivery pipes for filling the oil tank from casks on the ground. Engines fitted for oil burning are sent to South Africa, Russia, etc. Messrs. Fowler's fine engine, suitable for burning oil on the Holden's system, is illustrated. In the colonies and some foreign countries no coal or oil is to be had at a reasonable price; then wood, straw, megass, cotton stalks and other vegetable refuse must be used. For burning wood an extra large firebox is required, with a rack, or racks, for carrying a good supply. The engine should be fitted with a spark catcher on the chimney top and a screen in the smokebox. An extended smokebox would be an advantage. The colonial traction engines are fitted with extra large driving wheels, and for some districts the wheels are made wider than usual. The engines are also modified in construction, so as to raise the ash pan considerably further from the ground, to enable them to travel over rough roads, and uneven places where no roads exist. The ash pan is made to hold water. For sandy roads tee-iron strakes are fitted to the driving wheels.

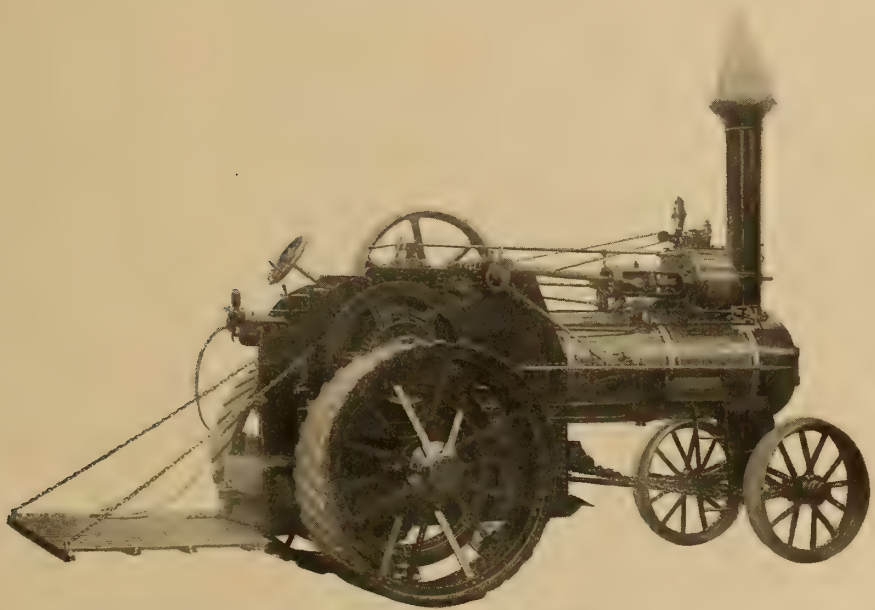
Road locomotives for the colonies are occasionally fitted with water-tight ash pans for crossing spruits and shallow rivers.

A large number of special straw-

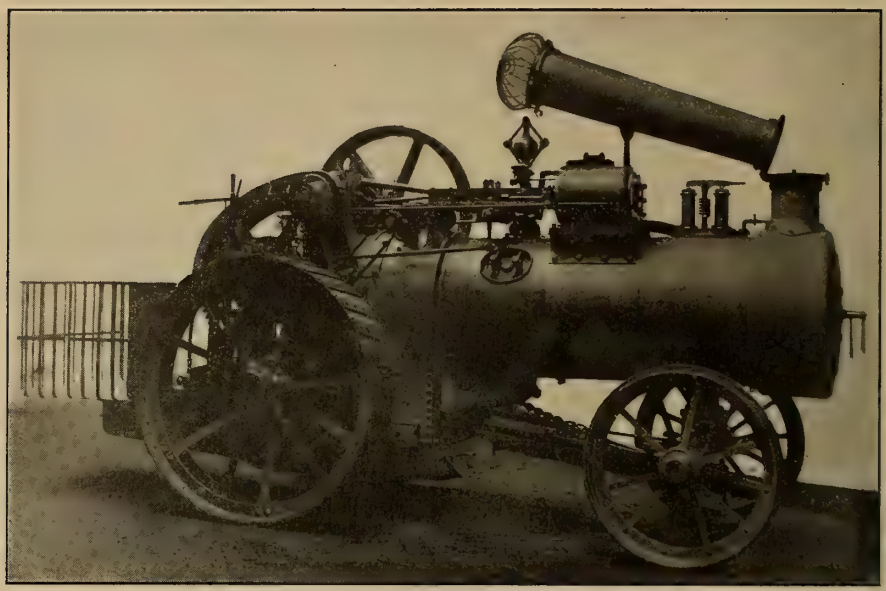
TABLE OF COMPOUND ROAD LOCOMOTIVES WITH ENLARGED FIREBOXES FOR SOUTH AFRICA BY FOUR LEADING MAKERS.

	A.	B.	C.	D.
Diameter of high-pressure cylinder	7 ins.	6¾ ins.	7½ ins.	7 ins.
Diameter of low-pressure cylinder	11 ins.	11½ ins.	12 ins.	11½ ins.
Length of stroke	12 ins.	12 ins.	12 ins.	12 ins.
Working pressure	160 lbs.	180 lbs.	180 lbs.	180 lbs.
Hydraulic test pressure	250 lbs.	300 lbs.	275 lbs.	300 lbs.
Diameter of driving wheels	7 ft. 0 ins.	7 ft. 0 ins.	7 ft. 0 ins.	7 ft. 0 ins.
Width of driving wheels	20 ins.	18 ins.	24 ins.	20 ins.
Diameter of leading wheels	4 ft. 6 ins.	4 ft. 6 ins.	4 ft. 6 ins.	4 ft. 7½ ins.
Width of leading wheels	9 ins.	9 ins.	12 ins.	9 ins.
Height to top of fly wheel	9 ft. 9 ins.	...	...	9 ft. 4 ins.
Length of engine over all	19 ft. 1 in.	19 ft. 2 ins.	...	19 ft. 0 in.
Width over hind wheels	7 ft. 11 ins.	7 ft. 6 ins.	...	8 ft. 5 ins.
Number and diameter of tubes	48—2 ins.	...	31—2½ ins.	41—2 ins.
Total heating surface	178 sq. ft.	164 sq. ft.	174 sq. ft.	156 sq. ft.
Grate area	7.7 sq. ft.	7.5 sq. ft.	9.0 sq. ft.	6.6 sq. ft.
Tank capacity	393 gals.	320 gals.	500 gals.	311 gals.

burning traction engines are shipped yearly to the Argentine Republic by some of the chief British agricultural engineers. Thirteen or fourteen years ago Messrs. Clayton & Shuttleworth and Messrs. Ransomes, Sims & Jefferies carried out experiments with straw-burning traction engines, and the two firms sent out two engines for the work; but they were too small. From these early failures it was discovered that a larger and special type of traction engine must be designed for the work. Messrs. Ransomes were the pioneers whose traction engines were successful. After they had solved the problem it was easy work for other firms to follow. At the present time Messrs. Ransomes, Clayton & Shuttleworth, Ruston & Proctor, Marshall Sons & Co. and Messrs. J. & H. McLaren supply engines and thrashing machines to this market. The boiler is the chief feature in these engines; it is very large for the engine that is mounted upon it. The firebox is extra spacious, and has a grate area of nearly 10 square feet; a large amount of straw must be consumed to keep up steam for enabling the engine to drive an extra large thrashing ma-



TRACTION ENGINE FOR ARGENTINA. MESSRS. CLAYTON, SHUTTLEWORTH & CO., LINCOLN



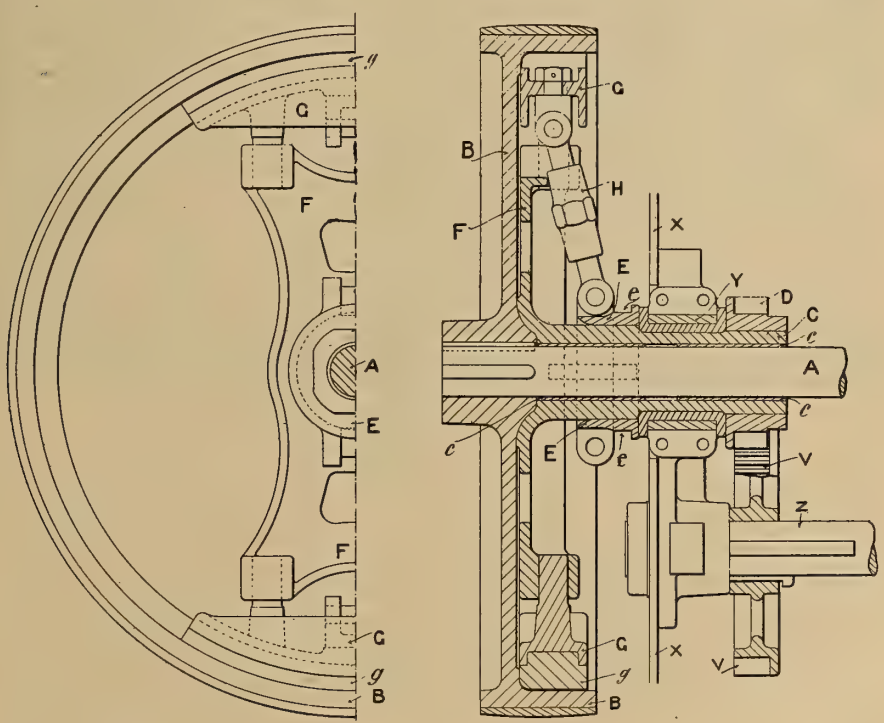
AN EARLY ENGINE. MESSRS. CLAYTON & SHUTTLEWORTH, LINCOLN

chine. A 9½ inches by 12 inches single-cylinder engine of this type has developed 50 horse-power on the brake when the boiler was fed with straw, and over 60 horse-power when the boiler was supplied with coal. The firebox is provided with a baffler plate, and means are used to prevent the small pieces of straw from passing over the baffler plate in an unconsumed condition and blocking up the tubes. A small door is fitted in the firebox side for cleaning off the straw cinders from the tube ends. At one time the Head & Schemioth's feeding apparatus was used, but afterwards the straw was forked into the firebox and spread by hand. The stoker stands on the rack on which the straw is thrown; he forks it through the large furnace self-closing door. The engine driver stands on the platform above, on a line with the countershaft. In addition to the ordinary pump fitted on the boiler barrel a steam pump is provided. It is so arranged that it can raise water from the cart into the engine tank. By another change the water can be drawn from the tank and forced into the boiler. A hose of sufficient length is supplied for putting out accidental fires of the straw and for slacking the ashes in the prolonged part of the ash pan. The weight of the engine is reduced to the utmost, to prevent it from sinking into the soft land. The driving wheels are made of large diameter, and up to 36 inches on the face for the same purpose. Some of the engines are made of extra size for ploughing by direct traction. Among the illustrations is shown a large compound straw-burning traction engine by Messrs. Ruston, Proctor & Co. The compound cylinders are on the side-by-side principle—a better practice than the tandem style, as adopted by the North American makers for the Argentine market. The Clayton & Shuttleworth's, the Ransomes' and Davey-Paxman's engines are of the fixed-axle type; the hind wheels are driven on both sides of the engine. The spur rings being riveted near the periphery of the driving wheels, allows them to be constructed as light as possible. Messrs. Clayton & Shuttleworth's traction engine has very wide driving wheels and deep

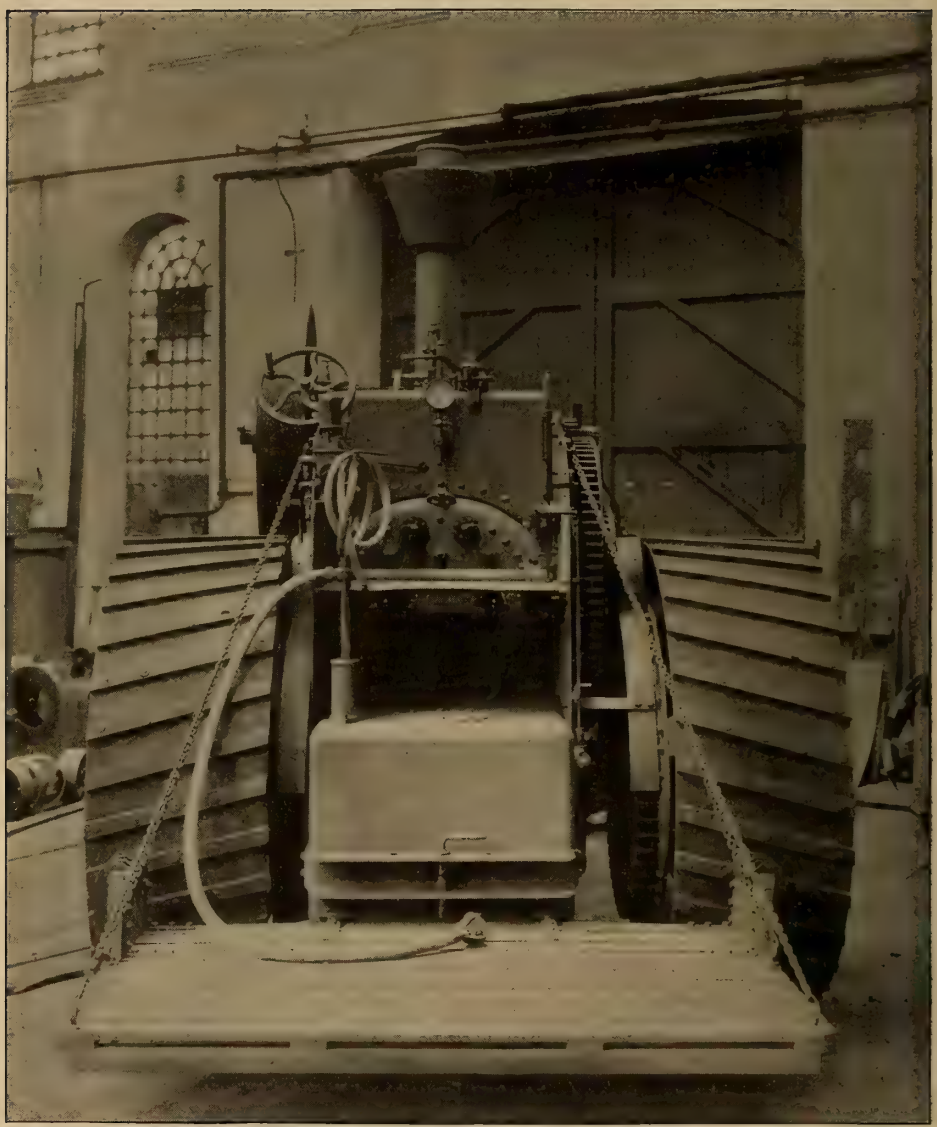
and widely-spaced cross-strakes for negotiating the Argentine plains.

An important part of the Argentine traction engine is the use of a friction clutch for communicating the power from the engine crankshaft to the driving wheels, engaging or disengaging at will. Messrs. Davey-Paxman's straw-burning traction engine is provided with a friction-clutch block on the fly-wheel rim, the friction clutch of which is shown in detail.

In most of the clutch arrangements used on the Argentine traction engines the fly-wheel, the sliding collar and the first-motion pinion are all arranged outside the bearing, causing a great overhanging weight without any support. The new patented clutch obviates this by placing the wide first-motion pinion inside the bearing and the other two details of the arrangement outside the bearing. The frame *F* is a steel casting formed in one with the sleeve *C*. This sleeve is mounted in the main bearing *Y*, carried by the horn plate *X*, so that the sleeve is free to rotate in the bearing and the crankshaft is free to rotate in the sleeve. On the end of the sleeve *C*, inside the horn plate *X*, is fixed a main spur pinion *D*, which gears with the spur wheel *V*, mounted on the first countershaft *Z*. On the sleeve outside the horn plate is mounted the moving collar of the clutch, and by a powerful lever and catch plate the shoes *G*, *G* are made to move radially outwards and engage and grip the interior surface of the flange of the fly-wheel. By means of a clutch the engine can be started and allowed to run freely at full speed. When the clutch is applied slowly or quickly, as the case may be, the power is transmitted to the driving wheel. Carefully and intelligently used, the clutch is a notable improvement to the traction engine; but improperly used, it may be a positive



FRICTION CLUTCH. MESSRS. DAVEY, PAXMAN & CO.



TRACTION ENGINE FOR THE ARGENTINE REPUBLIC. MESSRS. DAVEY, PAXMAN & CO., COLCHESTER

danger. All the Argentine traction engines are fitted with clutches, but these are not applied on engines used elsewhere. Among the illustrations is shown a longitudinal section of an American traction engine boiler for burning straw; the round hole in the firebox side is for cleaning the end of the tubes from cinders. When the Argentine engines are traveling or ploughing by direct traction a wagon of water and straw generally accompanies them, and the straw is thrown on to the rack of the engines.

Messrs. John Fowler & Co. manufacture a traction engine for the Argentine suitable for thrashing and ploughing by direct traction. The driving wheels of this engine are of extra width, a widening strip having been added to the ordinary wheels. The supplementary ring for widen-

ing the tires is well secured to the tee-iron of the main ring, and this extra ring has ten spokes of its own, in addition to the spokes in the main wheel. The ploughing attachment is fastened at one end by a chain to the nave of the wheel and the remaining part of the bar to the engine itself. An awning covers the engine from end to end. A large firebox and boiler are suitable for burning straw, and, by altering the fire bars, wood or coal could be used as fuel. The chimney is fitted with a damper and a spark-catcher. A useful box is hung to the front axle. The engine is made as light as possible consistent with the heavy work it has to perform. Messrs. Fowlers use the compound side-by-side cylinder system for most of their engines. Messrs. Clayton & Shuttleworth are fitting some of their Argentine engines with tandem compound cylinders like the American engines.

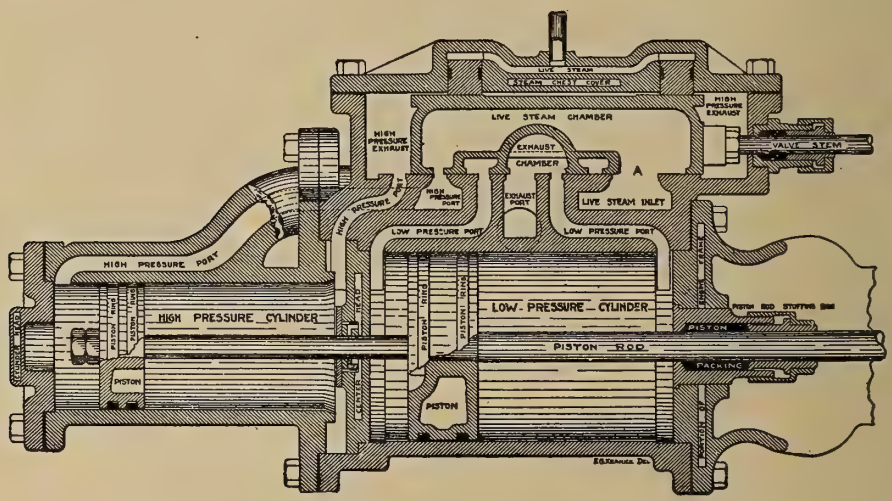
The Argentine engines have been dealt with at great length, because an exceedingly large trade is done by all the leading traction-engine makers of Great Britain. A neat special colonial road locomotive by Messrs. Chas. Burrell & Co. is shown. The engine is double-geared on the last motion in a similar way to the traction engine made for the Argentine. Engines of this type are employed in New Zealand for ploughing on the direct traction system, turning ten furrows over simultaneously. One is used for hauling Kauri logs in New Zealand. Many more are at work in India, Russia, Peru, Turkey, Austro-Hungary, and a considerable number of foreign governments are employing these engines on many forms of work. A powerful traction engine has been built for the South African market. It is arranged so that the motion work is carefully covered, in consequence of the enormous and frequent

STEAM TRACTION ENGINE FOR ARGENTINA. MESSRS. JOHN FOWLER & CO., LEEDS

dust storms to be encountered in that country. The gearing is completely covered in. A special draw-bar is seen for attaching ploughs for direct ploughing. A spacious fore tank is fitted beneath the boiler barrel. Messrs. John Fowler & Co. are the makers.

Messrs. Aveling & Porter build a fine road locomotive for colonial purposes. It is fitted with side-by-side compound cylinders, with outside steam chests. The cylinder casing is firmly bolted down to the smokebox end of the boiler barrel. High-pressure steam can be admitted to the steersman or engine driver. All the gearing is effectively cased in, to exclude dust from the wearing parts and the teeth of the wheels. The steering chain barrel is connected to the front of the fore tank. An awning is provided over the greater part of the engine; a footboard is fitted for the use of the driver when filling the oil cups on the cylinder and adjoining working parts.

A number of Messrs. McLaren's special road locomotives are employed in New Zealand for wool carting, for ploughing by direct traction, and for thrashing purposes.

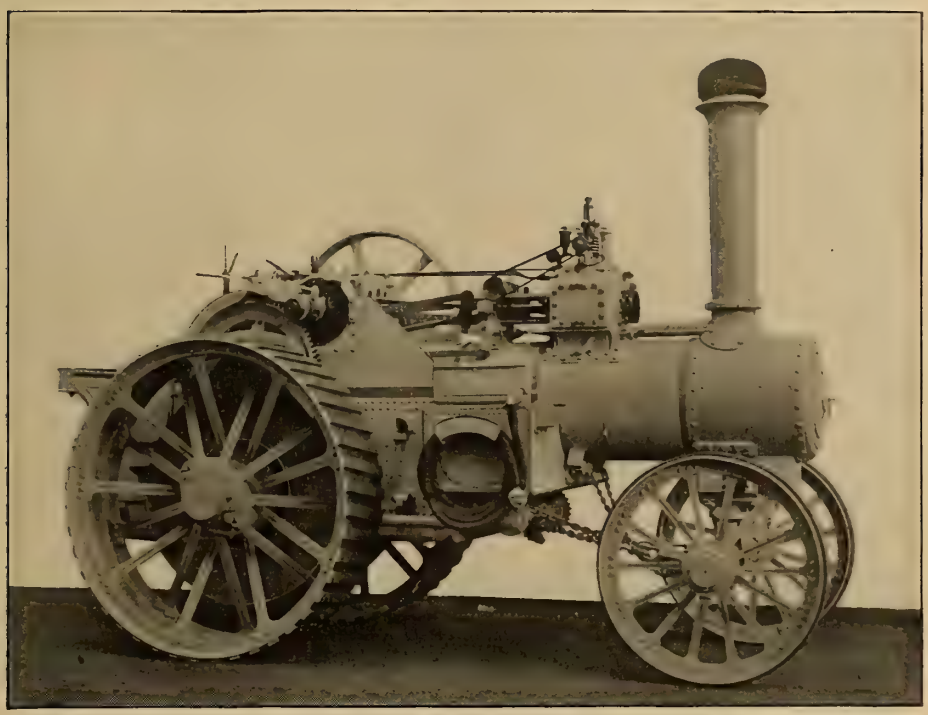


THE CASE ARRANGEMENT OF TANDEM CYLINDERS AND BALANCED VALVES

low-pressure steam chest for starting under a load, or for mounting a hill or traversing rough ground. A very large feed-water tank is fitted beneath the boiler barrel and connected to the hind tank by means of a pipe. The driving wheels are of large diameter and width, and the lowest parts of the tank and ash pan are more than 2 feet from the ground—a suitable provision for colonial uses. In order to prevent the driving wheels from casting sand over the engine parts, it will be seen that neat guards are fitted over the tires. These guards are useful as a safety device for preventing accidents to the

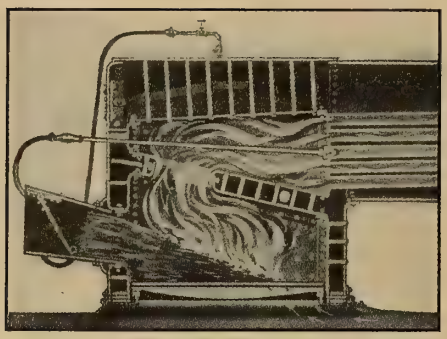
One of their engines, hauling a load, left Christchurch on the Friday evening about 7 o'clock, camped for the night at Kirwee (25 miles out) at midnight, went forward to Dalethorpe (45 miles from town) next morning, loaded the wagons, and was back at Christchurch late the same evening—90 miles round trip from 7 P. M. Friday to late Saturday evening. Some of the journeys are up and down steep passes through the mountain gorges in the Southern Alps, New Zealand. An engine taking a load up Porter's Pass, 3,090 feet above starting point, may be named. Messrs. McLauren's engines

are working in the Australian bush, in South Africa, in East Africa; several hauling engines are working for the Sultan of Zanzibar. The task of delivering the traction engines to purchasers is sometimes a matter of difficulty in some of the out-of-the-way colonial localities hundreds of miles from the nearest railway. In some instances the packing cases have to be discharged into the sea and dragged onto the beach by immense bullock teams.



TRACTION ENGINE. MESSRS. CHARLES BURRELL & SONS, THETFORD

Messrs. Clayton & Shuttleworth, in addition to the straw-burning traction engines for the Argentine, of which an enormous number have been made, have large road locomotives running in Australia, New Zealand, South Africa, Hungary, France, Spain, Portugal, Belgium, Bohemia, Germany, Italy, etc. The South African road locomotives are employed in hauling heavy loads and for ploughing by direct traction. The boilers have large fireboxes, and are made in accordance with the Transvaal boiler laws. Worthington pumps are used in some cases as a duplicate feeding apparatus. Large and wide driving wheels are adopted; the engines are fitted with three traveling speeds, mounted on springs, and built on the side-by-side compound system for a working pressure of 180 pounds per square inch. Some of Messrs. Clayton & Shuttleworth's traction engines sent to Portugal are used for ploughing on the direct system. A traction engine fitted with oil-burning apparatus is working in the Caucasus, hauling 27 tons up a hill of 1 in 9 cut out of a mountain side. The road is rough, and so narrow that two vehicles can hardly pass in any part. This is a good test for an 8 horse-power nominal single-cylinder engine. Other engines are working in foreign countries. Messrs. Clayton & Shuttleworth supplied a



STRAW-BURNING FURNACE. MESSRS. RUSSELL & CO.

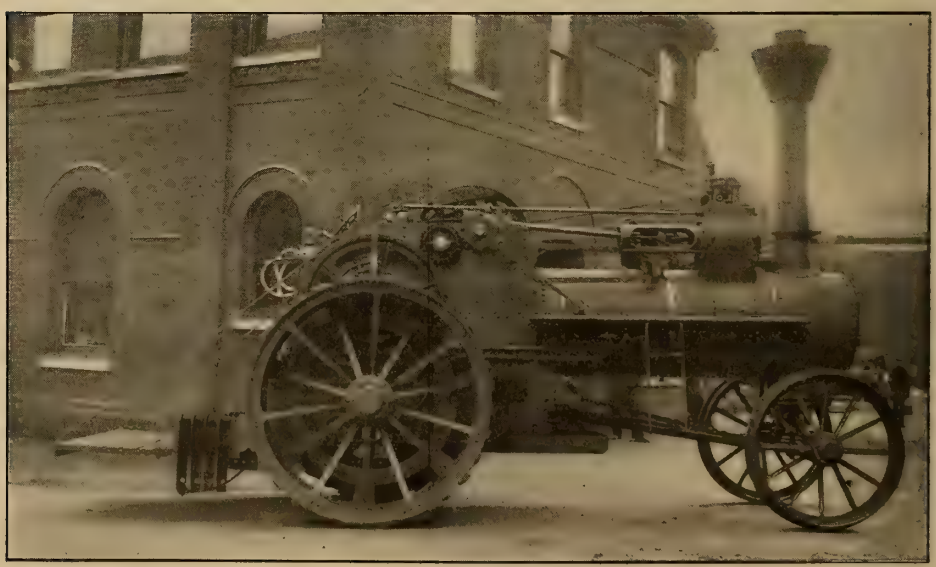
traction engine for His Highness the Khedive of Egypt. The boilers for the New Zealand trade are of special construction and built in accordance with Traile's rules.

Messrs. Ruston, Proctor & Co.'s compound traction engines, as sent to the Argentine Republic, are used for ploughing in the above country, as well as in Russia, Canada, India and other places. Ploughs are selected to suit local requirements. A 10 horse-power traction engine under favourable conditions will haul ploughs having twenty discs simultaneously to a depth of 6 inches.

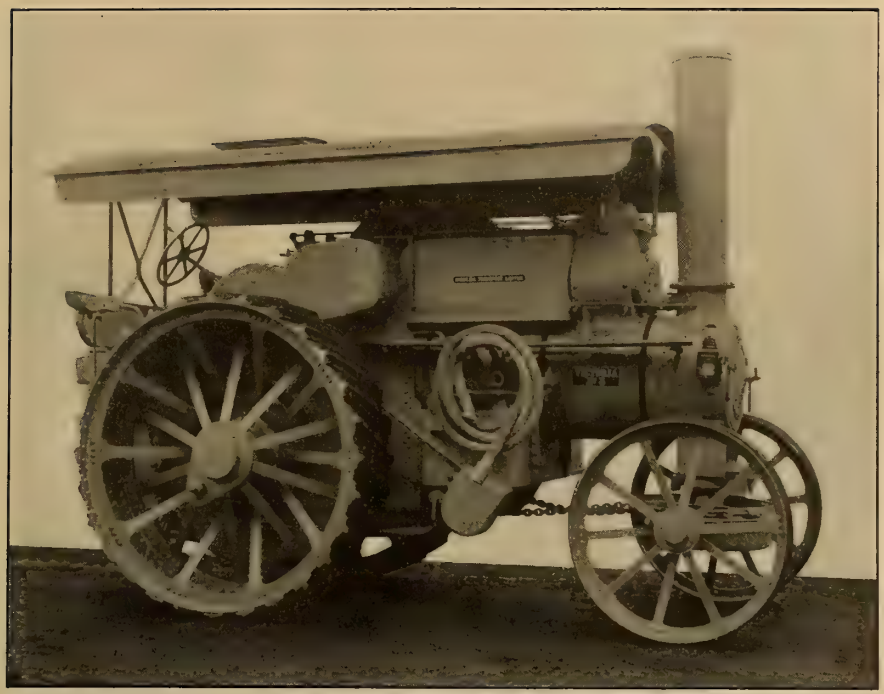
Messrs. Marshall Sons & Co. and Messrs. Rushton, Proctor & Co. are supplying small and light traction engines to the Continent (France and the south). The Marshall engine was exhibited at the Newcastle Royal Show. Only one speed is provided. Round iron spokes to driving wheels, and weight reduced in every part.

Messrs. Brown & May are commencing to ship their well-known little tractors, fitted with side tanks and other features, making them suitable for French service. In this instance only one traveling speed is fitted; no springs or winding drums are used, in order to eliminate weight. It will be seen that no reference has been made to the military traction engines that Fowler's, Aveling & Porter, McLaren and Bunnell's have supplied for foreign service in such large numbers.

Messrs. John Fowler & Co., in addition to the engines of their manufacture already mentioned, have traction engines at work in Uganda for carrying general stores and railway materials 30 miles from the rail head during construction. They have others doing useful work in West Africa, as supplied to the Portuguese

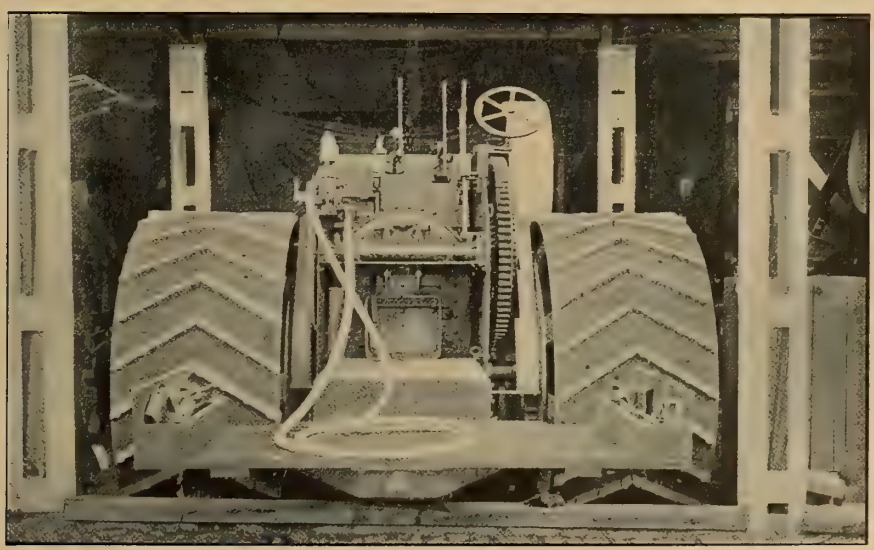


ROAD LOCOMOTIVE. MESSRS. DAVEY, PAXMAN & CO., LTD., COLCHESTER

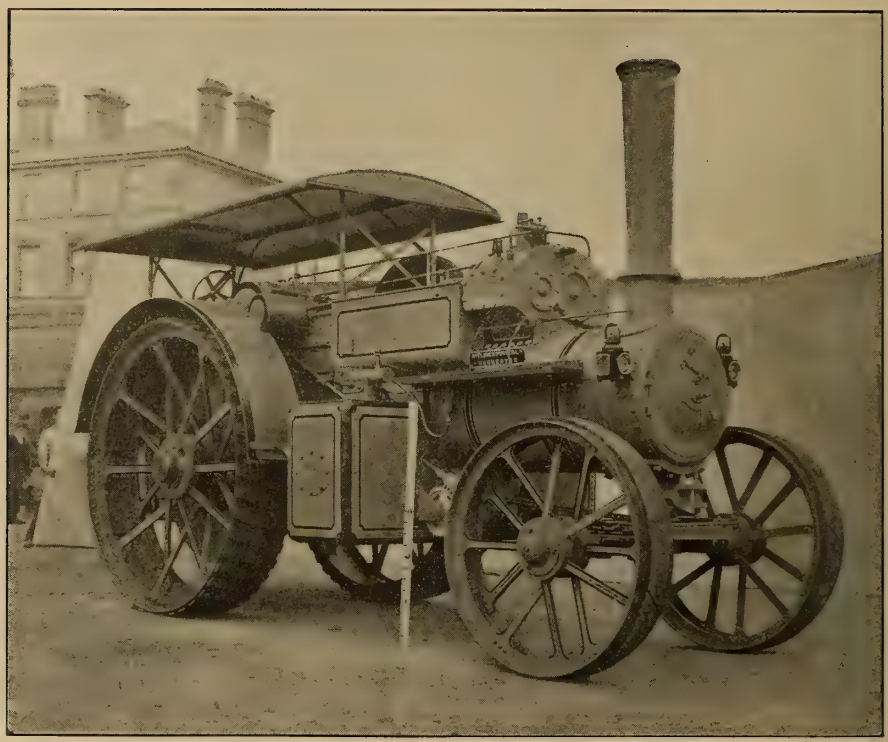


ROAD LOCOMOTIVE FOR RHODESIA. MESSRS. JOHN FOWLER & CO., LEEDS

Government. Messrs. Fowler & Co. supplied the first compound road locomotive to the Orange Free State. Many of their traction engines are specially adapted as feeders to the main railways in the colonies. Much direct ploughing is being done by Messrs. Fowler's engines in all parts



REAR VIEW OF TRACTION ENGINE FOR ARGENTINA. MESSRS. CLAYTON, SHUTTLEWORTH & CO.



ROAD LOCOMOTIVE FOR THE COLONIES. MESSRS. AVELING & PORTER, LTD., ROCHESTER

of the world. In the Solomon Islands one traction engine draws four gang disc ploughs. This is mentioned as a type of many more. They are used for irrigating purposes. A centrifugal pump is attached to the front of the engine and is driven by a belt from the fly-wheel; the traction engine is placed on the bank of the river, the pumps lifting water out of the river into a trench on much higher ground.

AMERICAN SHIPPING: ITS PAST, PRESENT AND FUTURE FROM A BRITISH POINT OF VIEW

By T. Good

IN view of the probability that the general question of shipping legislation will occupy the attention of the United States Congress and people in the coming year, and that a vigorous effort will be made to resuscitate the American merchant marine, it may not be uninteresting to review briefly the past history and future prospects of the shipping and shipbuilding industries of the United States from a British standpoint. Indeed, the whole subject is of profound consequence to British interests, for it may be that in the not distant future America will be our most resolute rival in the ocean-carrying trade. At one time the Americans were our strongest competitors on the seas, and that may be the case again, at a much earlier date than most people suspect. It will be well to take stock.

First, let us take a glance backward, for that history in connection with American shipping may repeat itself is much more than a possibility. Between the closing years of the eighteenth century and the middle of the nineteenth the American shipping industry was raised from a very low to a very high status. The progress of that period was the direct result of a special set of laws and customs. During the last fifty years American shipping has declined. It has dropped once more to a low status. It has decayed because it has been neglected—because the protective laws under which it had flourished were withdrawn. But if, as now seems likely, measures of a protective nature are once more extended to American ships, what is there to hinder our United States rivals attaining high rank again as a maritime nation?

When the first Federal Government was established, in 1789, the American merchant marine was in just as weak a condition, relatively to the trade of the country, as it is now. Its total gross tonnage was a paltry 123,000 tons. Nine-tenths of America's imports and exports were carried in ships which were not American. About seven-eighths of them were carried in British ships. But see what happened. The new government, in its very first act for the protection and encouragement of American industries, laid down a series of laws and customs taxes specially designed to withdraw American trade from foreign vessels. Under those laws American shipbuilding and shipping thrived exceedingly. Foreign vessels were driven out of the American trade as fast as American yards could launch ships to take their place. The gross tonnage of America's merchant marine grew from 123,000 tons in 1789 to 981,000 tons in 1810. In those twenty-one years the proportion of America's ocean commerce carried in American vessels rose from 10 per cent. to 90 per cent. of the total.

Protection and encouragement in one form or another—mainly in the shape of bounties and subsidies for home ships and high dues against foreign ships—continued down to 1861. Very generous mail subsidies were paid, and under that practical encouragement steamship building and owning attained high standing. The ocean-going tonnage reached 2,500,000 tons in the "fifties," and the United States flag was on every sea and in every port. In those days the United States built more ships than the United Kingdom did.

In 1855, for example, United States builders launched 583,000 tons of new shipping—a figure never reached by British builders until 1874. Down to 1855 bounties were paid even to fishermen and fishing vessels, for the deep-sea fisheries were regarded as the nursery of the navy. The shipping fraternity was as highly protected—and, we may add, as progressive—then as the iron and steel industry is now. In view of the present agitation for the re-introduction of shipping protection, it is well to recall these facts.

About 1885, however, the agricultural interests began a vigorous, not to say fierce, agitation for the withdrawal of the special favours enjoyed by the shipping trade. First one and then another favour was, in fact, withdrawn, and the tonnage of new shipping launched in the States dropped from 583,000 tons in 1855 to 214,000 tons in 1860, and to 174,000 tons in 1862. In subsequent years American shipbuilding recovered some of the lost ground, but only temporarily, and as late as 1886 the total tonnage launched reached only 95,000 tons. It has recovered again from that low ebb, but is still far below that high level which the natural resources and commercial interests of the country warrant; while, of course, shipping, as apart from shipbuilding, has been a steadily declining industry in America ever since 1855. In 1861 the subsidies and other favours were entirely discontinued, and from that day to this the American ocean shipping trade has been left absolutely outside the scope of the nation's protective laws. To-day the gross tonnage of the merchant marine of the vast United States of America (apart from lake, river and costal vessels) is less than a million tons—939,000 tons, to be exact—or little more than one-twentieth the tonnage size of the British merchant fleet.

The American shipping industry, deprived of a share of that protection which is afforded almost every other trade in the United States, has been unable to withstand the competition of other nations. From a position second only to that held by the United Kingdom in the middle of the nineteenth century, the American merchant marine has dropped to about the sixth place. Here are the latest figures:

GROSS TONNAGES OF MERCHANT MARINES

	Tons
United Kingdom	18,251,000
Germany	2,912,000
Norway	1,977,000
France	1,952,000
Japan	1,483,000
United States	939,000

The simple fact is that the American shipowner, unaided by the State, has been quite unable to hold his own in recent years. (The one existing American line to Europe to-day is the creation of a special mail subsidy law passed in 1891.) Burdened with dear ships and dearer labour, stores, provisions, etc., he cannot stand against the competition of the Britisher, who enjoys cheap ships and cheaper labour, or against the Germans, the Japanese and others, who have very cheap labour and liberal, not to say lavish, subsidies from their governments. That is the position in a nutshell.

For more than twenty years now a persistent agitation has been conducted in the United States in favour of protective shipping legislation and the resuscitation of the merchant marine. One school of thought advocates a discriminating tax against foreign shipping; another appeals for the payment of direct subsidies. The subsidy idea finds the most favour. The votes taken in Congress show a steady advance toward the direct subsidy policy. The United States Merchant Marine League has been very active, both in the press and on the platform, lately, and opposition to the "more ships" plea has been gradually worn down. For a long time the efforts of the League met with but scant encouragement; but recently events have happened which have brought

home forcibly to the public mind the necessity, alike on patriotic and on business grounds, for a much bigger fleet of merchant vessels. The recent spectacle of the United States Government being obliged to charter foreign ships to carry coal for the navy when on a cruise round the world seems to have touched the national pride, and has done much to bring the "more ships" doctrine within the range of practical politics, while the prospective opening of the Panama Canal is a great stimulus to the Merchant Marine League and the statesmen favourable to its work.

President Taft, nearly every member of the new Administration, and many influential members of Congress are pledged to the principle of ship subsidies. A bill is to be introduced shortly, and the debate upon the measure and its ultimate shape and outcome will be watched with great interest in this country. That the subsidy agitation will be carried to a successful issue, and some far-reaching measure for the encouragement of American shipping passed into law in 1910, seems more than a probability.

It is urged, apparently with considerable effect upon public opinion, that the huge expenditure upon the Panama Canal will have been undertaken mainly for the benefit of foreigners unless the United States possesses a vastly augmented fleet of merchant ships by 1915, when, it is anticipated, the great canal will be opened. The President himself strongly insists upon this point, and declares that the completion of the canal will revolutionize the carrying trade between East and West. Mr. Taft's own suggestion for strengthening the merchant marine is that Congress provide some six or eight million dollars a year to assist the creation and upkeep of a number of regular lines between the East Coast ports of the United States and South America on the one hand, and between West Coast ports and the Orient on the other. This, the President thinks, would equalize the benefits between the Atlantic and Pacific ports of the Union.

The same idea, in the main, finds expression in the bill which Mr. Humphrey is going to introduce. This bill also seeks to authorize the payment of liberal subsidies to American-built vessels carrying mails; to provide for the home registry of foreign-built ships of 5,000 tons and over owned by American citizens, on condition that they do not share in the subsidies; and for the establishment of lines of "naval auxiliary" ships to Argentina, Brazil, Chile, Peru, China, Japan, Australia and New Zealand.

The bill may not go through Congress without some modification; but that its main provisions will be embodied in an act, and a new era in American shipping commenced, seems now beyond question. It is recognized that this industry has been neglected too long, and it is argued that the system which worked so well in the first half of the last century in America and raised American shipping from insignificance to high prestige, and the system under which to-day the shipping industries of competitive nations are thriving—the subsidy system—should again become a part of United States law. Besides, that protection from the competition of rivals who possess cheap labour and materials which is afforded the manufacturing trades of the United States cannot logically be withheld from the shipping industry. And not only do America's maritime rivals possess cheap labour and materials, but, with one notable exception, every important country subsidises its shipping trade.

The example of Japan is not being lost upon the American politicians and public. Under a system of generous subsidies the tonnage of Japan's merchant fleet has risen from 200,000 tons in 1894 to 1,483,000 tons at the present moment, and is still growing, and likely to grow, at a rapid rate. Unless America does some-

thing—and does it quickly—Japan will monopolize the Pacific Ocean trade.

Germany's merchant marine has increased, in steamship tonnage, from 300,000 tons to very nearly 3,000,000 tons since the passing of the ship subvention bill in 1885.

The French merchant marine has grown from 900,000 tons to nearly 2,000,000 tons since 1881 under the subsidy and bounty policy.

Italy and Austria have ship subsidy policies; Norway has lately adopted the same system, and Sweden lends public money to her shipowners on generous terms. Even Free Trade Britain pays a price for mail carrying which is scarcely distinguishable from a subsidy, and American advocates of the subsidy policy are making much of the financial assistance given by the British Government to the construction and maintenance of the *Mauretania* and *Lusitania*.

Of course, it will be no easy task for our American rivals to raise and maintain a merchant fleet capable of meeting successfully the keen competition of British, German and Japanese ships. The cost of labour, both in building and navigating ships, is very high, and likely to remain high, in the case of the United States. The protection, or encouragement, to be extended to the American shipping industry must be substantial, or it will not avail. But that is a question for American statesmen. What we have got to recognize in this country is that if the United States Government decides to grant to the shipping trade a full measure of protection—the same protection from the competition of rivals possessing cheap labour and materials as is afforded the manufacturing industries of the country—then we may soon see in the American shipowner our keenest rival on the ocean. What America has done once she may do again. What she is doing now for her manufacturers in the home market, and what she is doing for her costal traders, she may do for her big ships in the ocean trade—protect them.

The gross tonnage of United States vessels engaged in the lake and costal trade totals very nearly 5,000,000 tons. This trade is reserved by law for vessels built at home; and it is mainly, almost exclusively, in supplying ships for this industry and the navy that American shipbuilders are employed. They do very little work for foreigners. In the event of the revival of the American ocean shipping trade under conditions of protection, shipbuilding will receive a great stimulus.

RAILLESS ELECTRIC TRACTION

By R. Lonneman

IT is only about twenty-five years since electric traction upon tramways has been a practical success, and the pioneer work of the Allgemeine Elektricitäts Gesellschaft in Germany, of Sprague and his associates in America, and of Siemens & Co. in England, has resulted in the enormous development of electrically-operated railways, not only in the streets of great cities, but also in the inter-urban railways which have supplanted the services of the steam railroads.

During the past ten years, however, there has been developed a special type of electric traction, this involving the use of an overhead wire for the transmission of the current, but dispensing with the costly railway construction upon which the cars run. This system had its beginning as long ago as 1882, when the well-known firm of Siemens & Halske built an ordinary omnibus to be propelled by an electric motor receiving its energy from an overhead wire, a small eight-wheeled carriage running on the wire and drawn by the omnibus itself. In this apparatus the overhead carriage was connected to the omnibus by a flexible cable, this serving both to draw the trolley and also to convey the current. Experiments with this apparatus were not continued, since the demands for street railway traction occupied all the time and efforts of the builders. In France a similar system of electric traction was originated by the Compagnie de Traction par Trolley Automoteur, this including some improved details, the system being designed by MM. Bonifiglietti and Lombard-Gérin, the name of the latter engineer being generally given to this type of electric traction.

The principal part of the contact apparatus consisted of a little carriage running on the two overhead wires, this being equipped with an electric motor, synchronized with the motor of the omnibus, so that the carriage always ran ahead, without causing any mechanical pull on the wires. This synchronism was secured by having the current which operated the motor of the overhead carriage given off by the direct-current motor of the omnibus. The little motor was of the three-phase type, and the synchronism was secured by the method of connection.

The flexible cable was usually made to contain six wires, two connecting with the poles of the omnibus motor, three running back from the collecting rings of this motor to the little carriage on the wires, and one auxiliary wire for stopping the motion of the overhead carriage in special cases, in order to prevent pull on the wire. When a regular passing place was arranged at the same spot an overhead switch was arranged to permit the trolley carriages to pass each other. If, for any reason, two omnibuses met at some other point on the line, it was possible for them to pass each other by exchanging connections with the overhead carriages. In practice, however, the high expectations aroused by these early devices were not fulfilled. The trolley carriage often fell off the overhead wires, and the wear upon the wires was very great. The operating expenses were also very high, and thus the first installations were not commercially successful. They

CAR WITH SINGLE TROLLEY ROD AND DOUBLE CONNECTION ON THE CITY RAILROAD IN MULHOUSE, ALSACE

demonstrated, however, that it was possible to run electrically-propelled vehicles of this kind upon common roads, and showed that it was necessary only to improve the details to render such a system a success. Later improvements, due to the work of Schiemann, have resulted in making the railless electric trolley a practical and commercial system, and traction upon this system is now in regular use for passengers and merchandise in Germany and France, and is also being tried in Holland.

The railless traction system may be considered as holding a place between that of the petrol motor omnibus and the electric tramway. It shares with the motor 'bus the advantages of large saving in initial capital expenditure and the ability to be steered around obstructions, while at the same time it has the advantage of using the series electric motor, which possesses ideal properties for traction purposes.

The great feature of the railless system, of course, is the freedom from the expense of track construction, and consequently, also, from the additional high costs of right of way. In the matter of operating cost the railless system is free from the expenses of maintenance of track, and has a correspondingly low burden for amortization. The consumption of current per ton-mile is greater than with the tramway, but this is largely offset by the fact that the weight of the vehicle is much less. If the consumption of current is less than double, and the weight of vehicle is about one-half, the actual cost for current will naturally be less for the railless system than for the tramway.

The latest line to be constructed on the railless system is at Mulhouse, Alsace; but as working data of this are not yet available, we will give a description of the line at Neuenahr-Walporzheim, in the well-known Ahrthal, near Remagen. This line

extends from Neuenahr, the famous German "Kurort," via Ahrweiler, to Walporzheim, a distance of 5.5 kilometres, or about 3.4 miles. The total capital of the company is 140,000 marks, while a tramway would have required 350,000 marks, an amount of which the interest could never have been covered by the operation of the road. The energy for operating the motor cars is transmitted through two overhead wires, one being positive and the other negative, these wires being of hour-glass section, and separated by a distance of 50 centimetres, each wire having a cross-section of 50 square millimetres. The connections to the vehicle are made through two trolley poles, or in the later type, as at Mulhouse, by one double-contact pole. The contacts are made, not by the use of the ordinary trolley wheel, but by the use of a sliding aluminum block. The omnibus is provided with a series direct-current motor of 25 horse-power, this giving an ordinary speed of 18 kilometres per hour, or a little more than 11 miles, while a maximum speed of 25 kilometres per hour may be attained. The current, supplied at a pressure of 550 volts, is derived from the electric plant at the Kurort, the cost being 13 pfennigs per kilowatt-hour, this corresponding to about 5½ pfennigs per car-mile.

It is usual in nearly all motor omnibuses—and, in fact, all self-propelled vehicles which do not run on rails—to apply the power to the rear axle, on which the greater part of the weight of the vehicle is carried, while the front wheels are carried on a separate pivot and connected mechanically to the steering wheel. In this system, however, a radical departure is made from this practice, and the forward axle, carried on a two-wheel bogie, is the one to which the motor is attached. This bogie is pivoted on ball-bearings and connected to the steering wheel through a reduction gearing. This construction materially reduces the danger of side slipping, and renders it much easier to guide the vehicle in the midst of ordinary traffic. The control of the vehicle is also simplified

CAR WITH ONE TRAILER AND TWO TROLLEY RODS ON THE WAY BETWEEN NEUENAHR AND AHRWEILER

by the convenient arrangement of the operating levers, steering handle and electric brake, while an ordinary foot brake is also provided. The rheostats, of a novel type, occupy a very small space.

At Wurzen there is a road of 6 kilometres in length upon this system used for hauling merchandise only, two motor cars being used on this line. The general arrangement is the same as described above, except that these cars are carried on two two-wheeled bogies, connected mechanically. These cars have motors of 25 horse-power, as above.

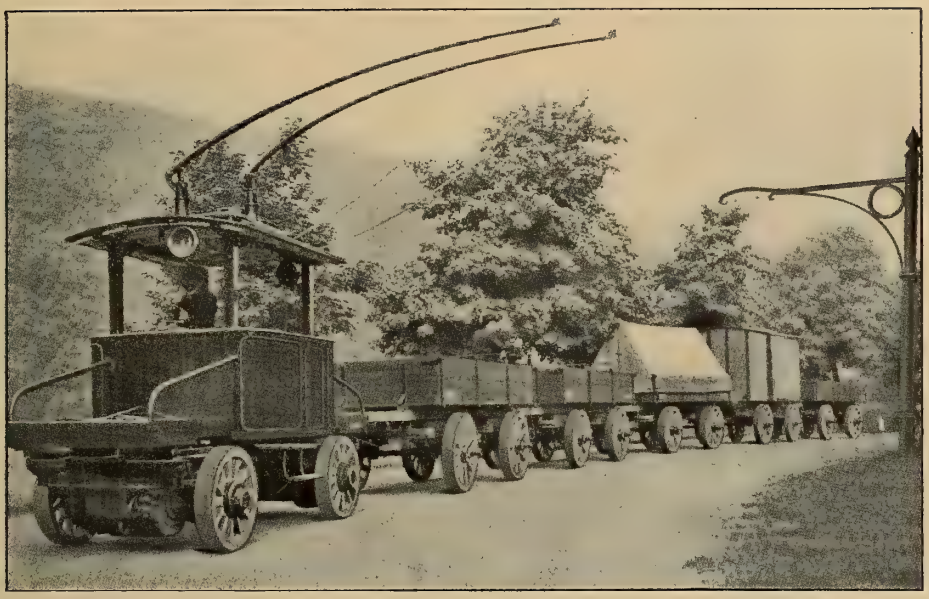
In the following table are given the figures for the operation of the Neuenahr line, the service being in car-kilometres and the receipts in reichmarks (20 reichmarks being taken as about £1 sterling and 4 reichmarks as about $1).

An examination of the figures will

Month. 1906	Car Km.	Trailer Car Km.	Total Car Km.	Receipts Marks.	Receipts Car Km.	Consumption Kw. Hours.	Consumption Car Km.
May, 7 days.....	2,187	670	2,522	1,114.00	0.45	979	390
June.....	7,668	4,520	9,928	3,364.60	0.34	3,223	325
July.....	8,117	5,110	10,667	3,835.00	0.36	3,389	320
August.....	8,510	5,208	11,114	4,088.30	0.372	3,421	308
September.....	8,231	2,638	9,550	2,913.10	0.304	3,515	370
October.....	4,525	.....	4,525	1,174.10	0.26	1,828	404
November.....	4,298	.....	4,298	946.15	0.22	1,710.5	400
December.....	3,894	.....	3,894	892.00	0.23	1,934	496*
1907							
January.....	3,927	.....	3,927	900.00	0.235	1,943	504*
February.....	3,676	.....	3,676	866.00	0.236	1,860	506*
March.....	4,137	270	4,272	1,216.20	0.284	2,132	498*
10 months 7 days.	59,170	18,406	68,373	21,309.45	0.312 Average.	25,943.5	380 Average.

* Roads impeded by snow and thaw.
Car km. of trailers taken as one-half motor car kilometres.

RAILLESS ELECTRIC CAR IN THE TOWN OF NEUENAHR



FREIGHT TRAIN HAULED BY RAILLESS ELECTRIC LOCOMOTIVE NEAR WURZEN, GERMANY

OPERATING EXPENSES.

Distance covered, 68,373 Car Km.	Reichmarks.	Per Car Kilometre Pfennigs.
Management, printing, etc.....	2,000	2.9
Wages and uniforms.....	8,134.38	11.9
Power (25,943.5 kw. h. at 13 pf.)	3,372.65	4.9
Repairs and maintenance.....	904.31	1.3
Oil, lighting, tool depreciation...	929.14	1.4
Rubber tires.....	2,319.90	3.4
Insurance (fire, accident) and minor small expenses.....	1,371.22	2.0
In 10 months 7 days.....	19,031.60	27.8

show a small profit, although they relate to the first operating year.

It has been shown that this system can be used advantageously in locations in which the ordinary horse-drawn omnibus is operated successfully. It is also available for use in portions of cities in which the narrowness of the streets will not admit of a tramway, and it may be found useful in extending the radius of existing tramway systems until the growth of traffic warrants extensions of the main lines by carrying passengers to the terminals.

COAL MINING ACCIDENTS IN THE UNITED STATES AND THEIR PREVENTION

By J. A. Holmes

The following paper, originally presented before the National Civic Federation in New York, is here reprinted by the especial permission of the Director of the United States National Geological Survey, having been prepared by the expert in charge of the Technologic Branch of the Geological Survey.—The Editor.

THE coal industry of the United States in its phenomenal growth has nearly doubled during each succeeding decade of the past eighty years. It has had to do more than keep pace with the increase in population, for while it supplied less than one ton of coal per capita to the American people in 1880, it has had to supply nearly ten per capita during 1908. Its growth has been too rapid for systematic development, and the industry to-day represents a great host of scattered, warring, discouraged elements, without organization or cooperation.

In this industry are now employed some 600,000 miners, who worked at some 6,000 different mines, and produce yearly about 500,000,000 tons of coal.

Not only is the nation increasingly dependent upon this coal for its heat, light and power for its manufacturing industries and transportation facilities, but this coal and other mineral products now contribute in tonnage more than 65 per cent. of the total freight traffic of the country.

The economic conditions upon which coal mining is based in America are fundamentally bad, and the evil consequences are so far-reaching, as to both time and extent, and are so essentially national in character, that this subject demands the earnest consideration of the country's best statesmen, as well as its best engineers.

(1) In spite of this rapid growth in the demand for coal, the normal productive capacity of American coal mines under continuous operation greatly exceeds this demand.

(2) Ruinous competition exists not only between the operators in the same field, but between the operators of one field as against those in another field, or in another State, where different mining laws and regulations exist.

(3) This competition is, first of all, driving out of the business the small operators, except where they find protection under local freight rates, and is forcing even the larger operator to mine coal under conditions which he cannot approve, but from which he finds no escape. If he and his fellow operators endeavor to "get together" and place the price of coal at the mine on a reasonable basis they go to jail under either a Federal or a State statute; and as the only alternative each must live (or succumb)by underbidding the other, which he can do only through wasteful and unsafe mining methods.

(4) Even when the demand for coal and the prices are at their best, under existing conditions the operator can mine only that part of his coal which can be taken out most cheaply and sold at higher prices, and the remainder must be left underground in such shape as may preclude its future recovery. And thus there is wasted yearly more than 250,000,000 tons of the nation's fuel supply.

(5) The American mine owner is as humane as is the mine owner of any other country, and he would like

to follow every practice and use every appliance for safety to be found in Britain, or France, or Belgium, or Germany, or elsewhere; but he pays his miners higher wages and, at the same time, receives for his coal at the mine less than half the price received for similar mined coal by the operator in these countries, and he must employ miners an increasingly large percentage of whom come to him unfamiliar either with the practices of the industry or with the language or traditions of the country.

(6) And the penalty which the nation is paying for this bad system is this increasing waste of resources and the still more unpardonable increasing waste of human life—the yearly loss of 250,000,000 tons of coal and the killing or injuring yearly of 8,000 to 10,000 men.

And what are the remedies for this bad situation?

(a) Investigations, such as are now being conducted by the government, as to the causes of mine explosions, and similar investigations as to the causes of mine accidents of other kinds and as to methods of prevention.

(b) Educational work among the miners and the lower active mine officials as to these causes and remedies.

(c) The training of men at each mine as to the best methods of using explosives, using electricity, handling of gases and dust, of timbering, of preventing and extinguishing mine fires; as to the methods of rescue work and as to the methods of first-aid-to-the-injured work.

(d) The development of better and more uniform mining laws, rules and regulations, based upon accurate data and experience.

(e) Active, determined co-operation between the miners and the mine management and the State inspectors in the enforcement of these rules and regulations, with a view to the maintenance of the safest possible conditions in every mine.

The above are all parts of the programme for lessening and alleviating mine accidents, but they do not complete the programme. It is an essential part of this programme that—

(f) The ruinous competitive system upon which coal mining in the United States is based at the present time should be changed, and that the price paid for coal at the mine should be such as will permit and secure safe and efficient mining—mining unaccompanied by either this large loss of life or waste of resources—mining which can have due regard to not only the safety, but also to the health and the comfort of the men who toil underground and whose labour is so essential to the welfare of the nation. All this can be done without adding appreciably to the burden of the average American citizen, without any increase in the price of coal at the poor man's cottage, and without the risk of any unreasonable restraint of trade.

There can be no permanent industry without reasonable profits. It is unjust and irrational that in this great and essential branch of industry reasonable profits should be dependent upon any unnecessary sacrifice of human life and unnecessary waste of resources, which we can neither replace nor restore, and which will be essential to the future development of the country.

This industry needs and deserves fair treatment at the hands of the American people, and upon its receipt of such treatment depends in no small degree not only the welfare of the operators—though nobody care about them—but also the welfare of the 600,000 miners who risk their lives in supplying the fuel for the nation's industries and the heat and light for the nation's comfort and convenience.

Current Topics

IT is interesting to note that after the successful trials of the *Clermont* by Fulton, on the Hudson, in 1807, the introduction of steam navigation had its next and most rapid development on the St. Lawrence River and on the Great Lakes. Apart from the early experiments of Symington, described at length in the issue of this magazine for October, 1907, it has generally been assumed that the first British steamboat was Bell's *Comet,* which was in operation on the Clyde in 1811. As a matter of fact, the first commercially-operated British steamboat was the *Accommodation,* which was started on the St. Lawrence River, running between Quebec and Montreal, on November 5, 1809, only two years after the *Clermont* made her initial run from New York to Albany. An interesting account of this boat appears in the *Quebec Mercury,* of that date.

The development of steam navigation on the Great Lakes forms a most interesting chapter in marine engineering, and the article of Mr. James C. Mills, published elsewhere in this issue, will be found of much value. In this connection we may be permitted to note that much of the early history of this period is preserved in a record kept by Captain James Van Cleave, of Lewiston, in the form of a scrap-book, with sketches and water-color illustrations, covering the period from 1809 to 1877, and now in the possession of the well-known marine architect and engineer, Mr. Frank E. Kirby, of Detroit.

As a matter of fact, the first steam-propelled vessels on the Lakes were the *Ontario,* built at Sackett's Harbour, and the *Frontenac,* built at Ernesttown, Finkus Point, both in the year 1816, so that the matter of priority was equally divided between the American and the Canadian sides of the Lakes.

THE importance of the motor in the continued development of the aeroplane is seen in the prize competition established by the veteran aeronaut, Mr. Patrick Alexander, and to be conducted at the National Physical Laboratory, at Bushy Park, during the present year.

The regulations of this competition, which have been published for the information of competitors, contain a number of conditions which must be fulfilled; but the most important one of these is that which requires that the motor—a machine of 35 horse-power, weighing not more than 7 pounds per horse-power—must be operated continuously for twenty-

four hours. It is true that three stops, aggregating not more than one half-hour in all, may be permitted during the course of this run; but the main fact appears in that the problem to be solved is one of reliability.

It is to the development of the motor that the present success of the aeroplane is due, and it will be upon the improvement in the motor that its further progress will depend. The question of motor weight has already been solved, and weights of less than 10 pounds per brake-horse-power are now readily attained, and these are entirely within practical limits. If long-distance flights are to be accomplished, it is well understood that the weight of fuel is more important than the weight of the motor, and this necessarily includes the question of fuel economy, not because of the necessity for the limitation of the cost, but because of the fact that the weight of fuel becomes the limiting factor in flying radius.

When flying becomes more general it is evident that stations at which the fuel supply may be replenished will become necessities, and it is entirely possible that interchangeable gasoline tanks will be used, permitting an immediate exchange, without requiring the delay involved in filling attached reservoirs.

THERE is now under way a transformation in certain social relations, due wholly to the work of the engineer, the magnitude of which is scarcely realized, even by the men to whose efforts it is largely due. The exploitation of the domain of the air, not only by the practical evolution of aerial navigation, but by the development of radio-telegraphy and telephony, is evidently destined to bring about momentous changes in international and personal relations.

It requires but a casual investigation to reveal to the general observer that the most important of national and commercial undertakings are dependent upon the limitations which have been imposed upon mankind by reason of his confinement to the surface of the earth. The whole system of land tenure and real property rights has grown out of the hard fact that man was originally compelled to remain upon the surface, and that those who have obtained control of the land have found themselves in a position to dominate the earth. This control still exists with regard to the products of the soil, but it is rapidly becoming obsolete, so far as the freedom of movement and of communication is concerned. Probably the most important function of many governments is found in the control of ports and the collection of customs, a power absolutely connected with the inability heretofore existing for anyone to enter a country except upon the surface of the land or water. The German philosopher Hegel long ago drew attention to the fact that seas should be considered, not as dividing countries, but as uniting them; and he also emphasized the fact that the really effective limitations of national boundaries were not the oceans, but the mountain ranges. To-day the engineer is providing such effective means of transportation above the surface that national frontiers in the ancient sense—frontiers which may be effectively guarded by a few soldiers and revenue officers—are certain to become obsolete, and to be looked down upon by the aerial traveler as the tourist on the Rhine now gazes upon the ruins of the feudal castles which formerly dominated that highway.

The vast sums which are now capitalized in connection with the construction and operation of the railways of the earth have been mainly absorbed in the acquirement of rights of way and in the building of the roadbeds. In like manner the great telegraph and telephone systems have expended large amounts in the construction of the overland lines and submarine cables through which the

messages from which they derive their revenues are transmitted.

Man has hitherto been a creature existing in two dimensions, while he has been perfectly familiar with the properties of three dimensions and has permitted himself to speculate upon the possibilities of still wider fields; but when he actually begins to occupy the space above the surface on which he has so long been creeping it is difficult for him to realize how profoundly all his ancient, precedent-encrusted traditions are to be affected.

Wireless communication is soon destined to render a great portion of the capital accumulated in the installation of existing systems of communication of rapidly diminishing value; aerial navigation demands no cost for right of way, and will respect neither national frontiers nor private boundaries and landmarks. Protest will be as unavailing against the expansion of the former as political dissatisfaction will be against the latter. The tremendous readjustment is inevitable, and the wise men will be those who, perceiving the futility of opposition, hasten to adapt themselves to the new environment.

GERMAN manufacturers are complaining at the severity of the competition in the electro-metallurgical industry. Ferro-silicon, for example, is selling at a price 40 per cent. lower than in 1907, while both aluminium and ferro-chromium are quoted at prices which are below the cost of manufacture.

It is not good that anything should be sold for less than cost unless the cost is unjustifiably high, for such prices cannot continue. The explanation given is that supply of these new products has outgrown the demand. Demand for new products is always slow. There is a natural tendency among users of any material not hastily to abandon something they have grown accustomed to use and have learned to understand. And there is still a certain good-will in business which causes orders to go to the old traveler's firm for some time after the user has come to the conclusion that it would pay him to change. He does not change even then. He begins to change only by first hinting at the newer material and hopes that the price of the older material will be cut down very soon. Only when the old price is maintained too long in the face of the better new material does he begin to order the newer stuff. To deviate the course of business and supply is slow work, and electro-metallurgy is not likely to escape the general lot.

THE influence of the engineer upon social relations is effective, not only upon methods of transportation and communication, but also very largely upon those portions of the labour question which have to do with the more difficult manual operations. It has generally been assumed that the work of the hands must constitute the larger portion of human effort, and by far the greater element in the so-called labour problem has tacitly been allowed to be considered as embodied in this department. As a matter of fact, the heavier and more brutal part of laborious undertakings is just the very portion which can be best performed by mechanical appliances. The lifting and transport of burdens, once one of the great occupations of human and animal effort, is now largely performed by traveling cranes and hoists, by industrial railways, and by other mechanical appliances. The lesser operations in machine-shop work, involving both manual effort and personal skill, are already largely superseded by mechanical methods. Few shops demand that the machinist shall show personal skill with the hammer and chisel or the file, since such work is performed far better and more expeditiously by the shaper and the grinding machine. Many machine parts are produced so accurately by means of the drop-forging press that very little fitting of

any kind is required, and the general introduction of automatic machine tools has made the mechanic a mere tender and not a machinist at all under the older definition of the term.

There are those who deplore the passing of the mechanic, considered as the man whose skill resided chiefly in his hands and largely in his muscular development; but such changes should be considered rather as elements in a larger phase of human evolution which may be read, to a certain extent, in the light of still earlier developments. We know how the effects of "villainous saltpetre" were deplored by the advocates of earlier chivalry, and can perceive how futile any efforts to oppose the use of such applications of natural forces proved themselves to be. The important point to be observed is that, in times past, as in the present, the natural tendency of mental inertia is to oppose the new and to endeavor to perpetuate the old. Those who would pass their rivals in the race should keep themselves continually on the alert to drop the older methods before others have been willing to allow themselves to accept any radical changes, and thus keep ahead of the general practice, to their own immense advantage. Attention has already been called to the tremendous influence upon the history of the world which would have been produced had Napoleon been sufficiently well-advised to accept the proposals of Fulton to use the steamboat in advance of any other great Power. To-day we have a similar situation with respect to aerial navigation. In industrial warfare the manufacturer who throws existing equipment into the scrap heap, to permit himself, at apparent loss, to be placed far in advance of his rivals, is soon in the lead; while the manager who, perceiving coming labour troubles in advance, introduces mechanical appliances to perform the work of discontented or unmanageable employees, finds himself in full swing while his rivals are in the midst of disputes and interruptions.

The most laborious and disagreeable operations in all departments of work are the very ones which can best be performed by machinery, thus relieving mankind of burdens which should never have been imposed, and at the same time removing the principal reasons for discontent and trouble.

It is one of the great duties of the engineer to remove the causes of trouble in performing the work of the world by enabling the burdensome physical effort to be accomplished by mechanical appliances, leaving to man the duty of directing the machinery, and thus working with his head rather than with his hands.

AS an example of the manner in which engineering skill has acted to attain security from danger, attention may be called to the subject of modern burglar defense, in the form of safes, bank-vaults and similar methods of safeguarding valuables. Formerly the principal means of protection was found in the provision of watchmen and other guardians; but with the extension of the subject some inanimate appliances became necessary, and thus the earlier strong boxes were superseded by the iron safe, and this, again, by the steel burglar-proof safe, followed by the modern vault. The older key-locks, once supposed to offer difficulties against entrance by their excessive complication, gave way before the far simpler and more secure combination dial-lock, which, when reinforced by a time-lock, to prevent even the combination from being used except within certain periods, long gave adequate protection. With the introduction of liquid high explosives came the necessity for preventing any access to the interior, even by the use of the most limpid of liquids, and hence the solid door, with elastic-packed joints, was evolved, carrying with it the necessity for the use of automatic bolt-work, operated by

powerful springs, and controlled wholly from the interior by the mechanism of the multiple time-lock.

Improved tools for attack have been met by the use of modern alloy-steels of great hardness and resistance, and thus all the latest resources of the mechanical engineer and metallurgist have been drawn upon to meet the ingenuity of the modern burglar.

At the present time the advantage is on the side of the safe-builder and lock-maker, and the number of attempts upon the modern bank vaults is so few that there is every reason to believe that the defense has become superior to the attack. The question is not dissimilar to that of the contest between the builders of artillery and the makers of armour plate, and each, in turn, makes progress, only to be surpassed by the other, each, in turn, forcing a step in advance until some obstacle, insuperable for the time, is reached.

In such work the engineer is obliged to act, both in investigation and in construction, as a detective, and use all the methods of his profession to discover weaknesses, as well as to provide means to remedy defects. Engineering methods have become the controlling influences in modern international warfare, and in a less conspicuous, but fully as effective a manner, in the warfare of society against its internal enemies.

IN view of the extending use of reinforced concrete for all purposes of construction, it is interesting to note the manner in which it is modifying structures which had been standardized in other directions.

It was entirely to be expected that concrete, reinforced by the use of imbedded steel rods or bars, should have been accepted for the construction of tanks and reservoirs for the storage of water, and some interesting examples of such concrete tanks have already been illustrated in former issues of this magazine. An extension of this idea, not altogether so obvious, but fully as satisfactory in practice, appears in the growing utilization of reinforced concrete for the building of coaling stations, especially at the way stations of railroads where the engines receive supplies.

Attention has already been called in these pages to the fact that solids in a certain state of sub-division may be handled by methods involving flow to an extent comparable with those already used for liquids. Water is stored in reservoirs, through which it is subsequently distributed through mains and secondary pipes to the points where it is required, and its flow is controlled by valves and spouts with ease and certainty. In like manner, coal may be stored in bins, and, within certain limitations, its movements may be governed by the laws of fluids, so that the whole system of handling such materials may be based upon experience previously obtained with liquids.

As a consequence of this method of treatment, the construction of coaling stations involves the use of bins which shall act as tanks, and into which the coal is delivered by conveyors, and from which it flows through chutes, controlled by valves, to the waiting locomotive-tenders.

The use of reinforced concrete for the construction of such coal-storage bins is becoming accepted, and some of the best of such structures are excellent examples of good design and work. The material is entirely free from danger of fire, an important element when the risks of the older wooden structures are considered, while the durability and freedom from necessity for repairs enable the question of first cost to be met by the reduced expense for maintenance.

There is every reason to believe that in the very near future wooden structures will be the exception for nearly all purposes along the lines of the leading railroads, an evolution greatly to be welcomed in the interests of safety and efficiency.

THE traffic question is becoming more and more acute in the larger cities, and it is becoming evident that something more than palliative measures must soon be considered, at least for the more congested portions of certain places. This state of affairs is naturally due to the operation of the well-known law that "facilities create traffic," and thus the continual provision of improved methods of surface and subsurface travel is working out its own results.

It does not follow that such improved systems of travel are undesirable. Both in London and in New York the provision of underground railways, whether in tubes or in tunnels, has been a notable improvement. The rapid introduction of the self-propelled vehicle, both in the form of the motor-'bus and in the shape of public and private automobiles, has enabled time to be saved and great numbers of people to be carried rapidly to their destinations, and to such extent these improvements have fulfilled their part in the improvement of facilities. At the same time such developments have been permitted to run their course without the exercise of any controlling judgment to utilize these powerful influences for the prevention, or at least the amelioration, of congestion. In some instances, particularly in New York, it seems as if the intention was to further congestion in certain localities, when it was entirely possible to direct improvements in such a manner as to aid in dispersing the multitudes.

There is probably no greater example of undesirable congestion than the Manhattan entrance of the Brooklyn Bridge during certain hours of the day, and many able men have endeavoured to devise some means for remedying the evil, but without success. This is doubtless because the methods of transportation are such as to deliver large numbers of people at the bridge entrance, obliging them to start anew from the line.

The subway, which runs the entire length of New York, was at first constructed to serve Manhattan only, and when it was extended to Brooklyn it might have been operated in a manner similar to the bridge, all passengers to Brooklyn being obliged to board the trains at the New York terminus, a method which would certainly have created a congestion centre even more difficult than that already existing at the bridge entrance. Instead of following this defective precedent, however, the trains were run under the East River continuously from Manhattan to points along the Brooklyn extension of the subway, so that any passenger in either direction was enabled to board the train at any convenient station and proceed directly to his destination. The result has been the distribution of the travel along the entire route, and although there was a noticeable increase in passenger traffic upon the opening of the Brooklyn extension, there was no local congestion created at any one point.

This experience is an ample indication of the manner in which a judicious management of facilities may be employed to prevent crowding. It should be clearly understood that a definite terminal of any transportation system has no proper place in a modern metropolis. On the contrary, such structures are evils of great magnitude—evils whose nature can clearly be foreseen and for the perpetuation of which there can be no more reasonable excuse than could now be offered by any one who would deliberately propose to create another "bridge crush" such as already exists daily at the entrance to Brooklyn Bridge.

New York is but a typical example of the manner in which congestion centres may be created or prevented. No engineer would dream of directing the flow of water or steam as the flow of human molecules is now deliberately guided, and when the engineer is given full control of the handling of multitudes perhaps the methods employed will become similar to those already successfully used with inanimate fluids.

IN a paper recently presented before the Society of Engineers by Mr. G. Allan Thomas, upon the status of the engineering profession, attention was called to a number of points of interest. Among these, the first is the loose manner in which the term "engineer" is applied to men in many departments of work, and often appropriated by those who have no proper claim to be so called. Another feature, which, unfortunately, is not confined to the profession of engineering, is the overcrowding consequent upon the attractiveness which appears in an occupation in which men have achieved great success, and which seems to offer an easy road to eminence and profit. That success is gained only by hard work, accompanied by thorough scientific training, is as true of the profession of engineering as of any other; but the failures which follow upon inadequate preparation and insufficient effort do not deter the incompetent from making the attempt.

As regards the advancement of the profession, Mr. Thomas advocates the organization of a central organizing body, composed of members of the most important professional institutions, for the purpose of obtaining government recognition and for the regulation and control of the status of the profession, including registration, education, minimum fees and invention and research. The extent to which this can be successfully accomplished has been considered more than once, both in Great Britain and in the United States; but, thus far, it has not been found practicable to produce any effective working plan. Leaving aside for the present the desirability of such a plan, we may remember that it is only by such a method that the legal and medical professions have succeeded in maintaining their status, and that in another department of work—the stock market—it would appear to be impossible to conduct business effectively and satisfactorily without the existence of such powerful governing bodies as the respective Exchanges of London and New York.

PROFESSOR SILVANUS P. THOMPSON, D. Sc., F. R. S., ETC.

A BIOGRAPHICAL SKETCH

THE name of Thompson (or Thomson) is remarkable for its eminence in the realm of science. Apart from the late Lord Kelvin (who was Sir William Thomson) and Sir J. G. Thomson, the president of the British Association during the current year, there have been a dozen or more owners of the name holding prominent positions at one time in various branches of medicine or physics. The subject of our sketch is another bearer of this honoured name, whose accomplishments and works have made him widely known in the fields both of pure and applied science, in the United States and over the rest of the world as well as in Great Britain.

Professor Silvanus Thompson was born of Quaker parentage at Gorle, in 1851, and acquired his early education at the famous Friends' School, in that city. Passing from there, he took his B.A. degree at London University in 1869, and completed his scientific education at the Royal School of Mines, the University of Heidelberg, and elsewhere. In 1875 he was bracketed first in science honors at London University, and took his degree of Doctor of Science in 1878. In the same year he was appointed professor of experimental physics at Bristol University, and in 1885 was elected principal of the City and Guilds Technical College, Finsbury, which he has held continuously ever since. As a teacher of physics and trainer of young electrical engineers he is considered to have no superior in England.

Professor Thompson is the author of several standard works on electrical science. His "Elementary Lessons in Electricity and Magnetism" ran into 40,000 copies within a few years of its first appearance, and, like his "Dynamo-Electric Machinery" (published in 1884, and now in its eighth edition), has been translated into several languages. In addition to these, he has published a life of Philip Reis, one of the inventors of the telephone, a life of Faraday, a work on the "Electromagnet," and another on "Polyphase Electric Currents." His scientific papers, contributed to the Royal Society, the Royal Institution, the Society of Arts and the Institution of Electrical Engineers, cover a wide range of subjects, from physical and geometrical optics, visible and invisible light and the arc lamp to magnetic images and rotary converters. He delivered the Cantor Lectures in 1883, 1890 and 1895, and his fluency in foreign languages was responsible for a pair of admirable lectures—one in Italian before the Volta Centenary Congress at Como in 1899, and another in German before the Urania Society of Berlin in 1901. He is a past president of the Physical Society, the Institution of Electrical Engineers, the Optical Society, and of the South-Eastern Union of Scientific Societies; a Fellow of the Royal Society, the Royal Astronomical Society, and of other learned bodies; an LL.D. of Birmingham; a member of the Royal Academy of Sciences of Stockholm, and

an honorary M.D. of Koenigsberg; he has been a senator as well as examiner in the University of London; was honorary vice-president of the Electrical Exhibition at Frankfort in 1891; president of Section G of the British Association in 1907. He was one of the delegates to the Electrical Congress at Chicago in 1893, when he read a paper on "Ocean Telephony," in which was advanced the idea of accelerating the speed of signalling in cables by the use of inductive shunts. He was also the first president of the Röntgen Society, and delivered the presidential address in 1897. He has just delivered his inaugural address as first president of the newly-organized Illuminating Engineering Society. In 1907 he was elected a member of the Athenaeum Club under the famous Rule II.

At the present moment Professor Thompson is earning fresh literary honours as the biographer of the late Lord Kelvin, a task upon which he has been engaged for the last two years. The amount of labour involved in this biography may be gathered from the piles of documents and correspondence still stored in his working library, the capacious shelves and cupboards of which contain the most famous collection of literature dealing with electrical subjects that is to be found anywhere in private hands. Here, exquisitely bound and carefully protected, are rare specimens of the earliest-printed books and manuscripts in which electricity is discussed, for Professor Thompson is an antiquarian and a zealot in his favourite researches, and has published admirable studies on the "De Magnete" of William Gilbert and the rare "Epistola" of Pater Peregrinus, together with reprints of the same. His bibliophile tendencies run over into other, more popular, channels as well, and he can exhibit to non-scientific friends a choice, if small, collection of early printed books and manuscripts on many subjects. His catholicity of taste is accompanied by great versatility of accomplishments. He is a water-color painter of no mean order, as anyone knows who has seen his sketches of Alpine mountain glaciers and Canadian scenery. He is also a deft artist in black and white, designs his own Christmas cards, and etched the portrait of Faraday for his biography.

Socially, Professor Thompson is one of the most popular and genial of men, seen at his best, perhaps, in the combined literary and scientific atmosphere of the "Sette of Odd Volumes," of which he is an honoured past-president, and to which he has contributed more than one memorable "opus column" of learning and wit.

GEORGE STEPHENSON

THE FATHER OF THE STEAM LOCOMOTIVE

INDEXED

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MODERN HIGH-SPEED LOCOMOTIVES

CURRENT AMERICAN PRACTICE

By J. F. Cole

PATENT OFFICE MAR 23 1910

IN the last ten years many radical changes have taken place in American passenger locomotives, to meet the demand for heavier and more powerful engines for modern requirements of speed and greater weight of trains.

For many years the eight-wheel 440 class, generally termed "American Type," was by far the most favored design for passenger service in this country. Within its limitations it was a type well adapted to meet the conditions with light trains of speed, boiler capacity, simplicity of design and low cost of repairs; but its possibilities were necessarily sharply defined on account of its wheel arrangement and location of boiler, because its steaming capacity could not be increased proportionately to its weight, partly on account of the short length of flues permissible, usually between 11 and 12 feet. The firebox is also restricted to a maximum width of 40 to 42 inches by the available space between the driving wheels, so that with fireboxes as much as 10 feet in length the maximum grate area which could be obtained was in the neighborhood of 34 or 35 square feet.

The adhesive weight possible with two pairs of driving wheels which can be safely supported on medium and first-class track construction with the ordinary weights of rails is between 95 and 120 thousand pounds.

During the period that the eight-wheel 440 class reached its highest development the ten-wheel or 460 class locomotive came into more or less general use for passenger service where the requirements of tractive power and adhesion demanded additional weight on drivers and the limitations of wheel loads necessitated the use of more than two pairs of drivers.

The ten-wheel 460 class permits an increase in adhesive weight of 50 per cent., because it has three driving axles instead of two. The flues are also lengthened materially, so that in a general way it is the 440 class with an additional pair of drivers.

The majority of ten-wheel engines have had fireboxes not exceeding 41 inches in width; but in the last five or six years a number have been constructed having a width of 60 or more inches, located over the top of the driving wheels. The depth of the throat or the space under the bottom of the boiler to the bottom of the foundation ring is, therefore,

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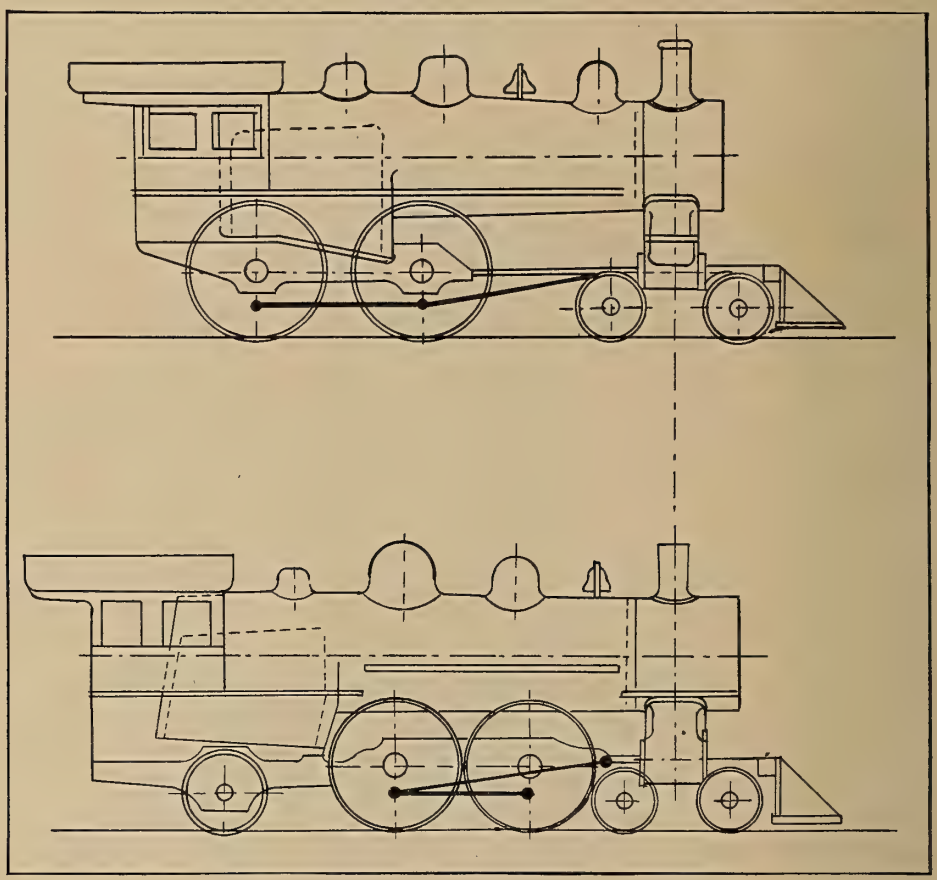


FIG. A.—AMERICAN AND ATLANTIC TYPES OF LOCOMOTIVES

somewhat restricted when driving wheels of large diameter are used.

The Boston & Maine 460 wide-firebox passenger locomotive and 72-inch driving wheels is an example of a successful design and proportion, Fig. 1, but which cannot be very much increased in weight, size of wheels, boiler or capacity on account of the limitations imposed by the design.

While many successful ten-wheel locomotives have grate areas of ample proportions, yet in a general way the same causes which limited the growth of the 440 class operated in a similar manner against the 460 class, and directed attention to the development of other classes of locomotives which were not subjected to such limitations in boiler capacity.

The Atlantic 442 class, with a pair of trailing wheels and the firebox placed entirely behind the rear driving wheels, was the next step. On Fig. A is given an outline of the two types, showing how it was possible by lengthening the boiler to obtain any required size of boiler and firebox, the width and depth of which were not restricted by the driving wheels.

Among the first engines embodying all the essential features of this class were the Chicago & Northwestern, Fig. 4, built in 1900 at Schenectady. The success of this class of engine was immediate, because it proved to have ample steaming capacity when developing its maximum horse-power. At the present time eighty-nine of this class have

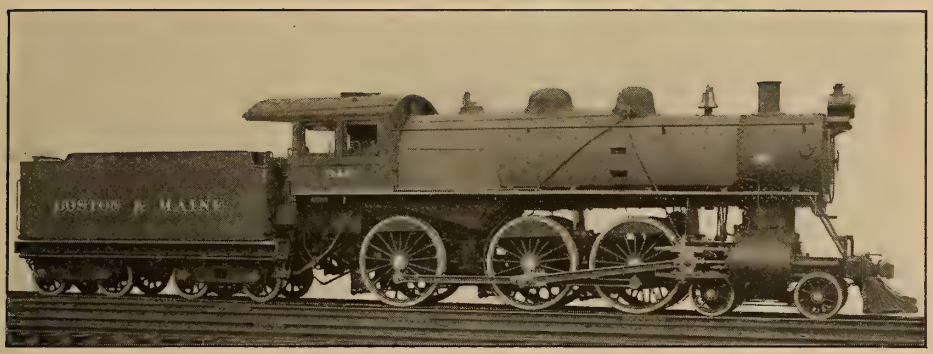


FIG. 1.—BOSTON & MAINE 460 CLASS, TEN-WHEEL TYPE LOCOMOTIVE

Total weight, 171,000 pounds

been built for this railroad with no change in proportions, and have hauled all their heavy fast passenger trains, which sufficiently endorses the foresight of the railroad and the builders in selecting this type of engine.

Great boiler capacity is necessary on high-speed passenger locomotives more than on any other class.

Small boilers, deficient in grate area and heating surface, can be forced to burn large amounts of coal per square foot of grate; but there is an economical limit which cannot be passed without waste of fuel. Therefore, while the small boilers, with valve gear and draft appliances perfectly adjusted, can be made to produce large quantities of steam, yet when the figures for the water and coal consumed or evaporated are considered, it will be found that the results are very uneconomical and unsatisfactory.

Among the most careful evaporative tests ever made on locomotives are those of Dr. Goss, at the Purdue University. In one of his reports it was shown that when 181.6 pounds of Indiana block coal was consumed per square foot of grate the evaporation of water was 4.77 pounds actual and 5.71 pounds equivalent from and at 212 degrees per pound of coal. When 120 pounds of coal per square foot of grate per hour was burned, the evaporation was 5.65 actual and 6.76 equivalent per pound of coal, a saving of 18.5 per cent.

One of the most striking characteristics of the modern fast passen-

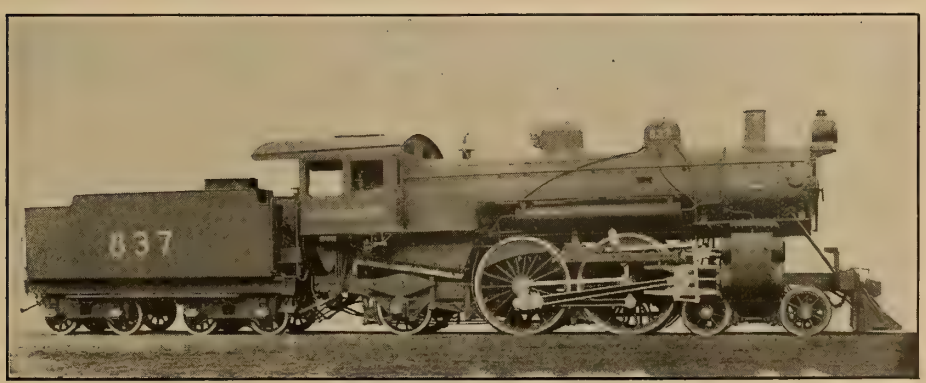


FIG. 2.—BOSTON & MAINE 442 CLASS ATLANTIC TYPE

Total weight, 175,000 pounds

FIG. 3.—PENNSYLVANIA 442 CLASS ATLANTIC TYPE LOCOMOTIVE

Total weight, 178,000 pounds

ger locomotive is its enormous boiler capacity when compared with earlier types. It is due to designs of locomotives having the firebox back of the drivers, similar to the 442 and 262 class, that such boiler capacity is possible. This, as before stated, permits the use of fireboxes of satisfactory depth and of a size suitable for the character of the fuel consumed. The designs also permit the use of long flues which, with an equal amount of draft, lower materially the smokebox temperatures when compared with the shorter boilers. This in itself is of great value, as any decrease in the temperature of the rejected gases is that much gained, so that the long flue, while it does not evaporate as much water per square foot of surface as the short flue, yet has great value in more completely absorbing the heat from the gases and in lowering the smokebox temperature.

In a general way, 120 pounds of bituminous coal per square foot of grate per hour may be accepted as representing the maximum amount of coal which can be burned in a locomotive grate with economical results. If this figure is exceeded, say to 180 to 200 pounds, the decrease in evaporation per pound of coal will be very great, so much so that one of the most noticeable economies which can be effected in locomotive design, as pointed out by Dr. Goss and shown by comparative figures, is by the use of large boilers carrying moderate pressures, say of 180 pounds. With boilers of ample capacity capable of producing sufficient steam for the maximum horse-power of the

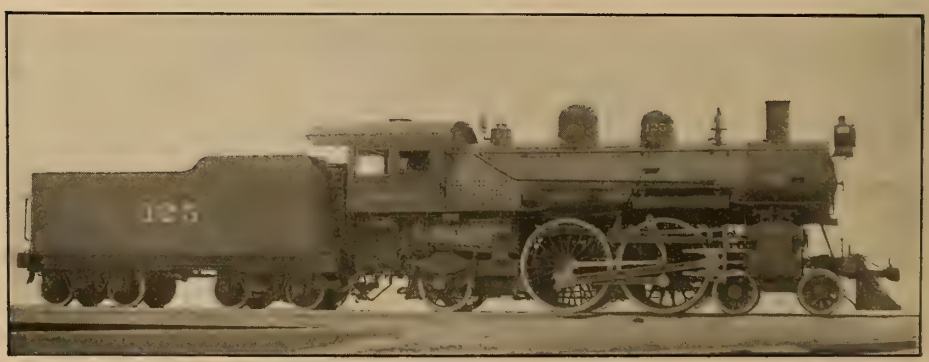


FIG. 4.—CHICAGO & NORTHWESTERN 442 CLASS ATLANTIC TYPE

Total weight, 180,000 pounds

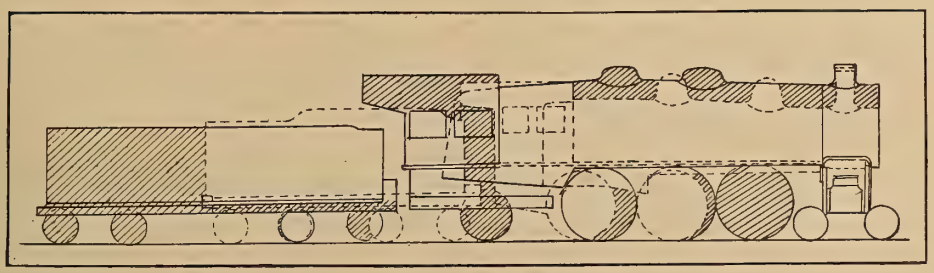


FIG. B.—PACIFIC 462 CLASS SUPERPOSED UPON EIGHT-WHEEL 440 CLASS

engine without exceeding the economical limits of combustion, and providing ample tube heating surface for the absorption, large economies can be effected. Further economies, as noted elsewhere, can be effected by superheating in combination with low steam pressures and increased tractive power.

The possibilities of the eight-wheel American type of engine was reached by its limited grate area in the neighborhood of 1,000 horse-power. Assuming 4 pounds of coal per horse-power-hour means a consumption of 4,000 pounds of coal per hour. A maximum grate area of 32 square feet requires the burning of 125 pounds of coal per square foot per hour. If this figure is much increased the evaporation per pound of coal is so much reduced that economical results cannot be obtained.

The limitation of the 462 type is somewhere in the neighborhood of 2,000 horse-power, with rail weight limitations of 60,000 pounds per axle.

The largest Pacific 462 class ever built is shown in outline, Fig. B, with one of the largest eight-wheel 440 type superimposed, to give an idea of the relative increase in growth in the past few years.

The curves in Fig. C are derived from a report of experiments made by Dr. Goss on the Purdue locomotive testing plant.

The first curve shows the relation between pounds of coal fired per square foot of grate per hour and the equivalent water evaporated from and at 212 degrees. The fuel used was Indiana Brazil block coal, thermal value 13,000 British thermal units. It shows when 40 pounds of coal were fired 8½ pounds of water evaporated, and when 180 pounds were fired the evaporation dropped down to 5.7. The indicated horse-power of the locomotive is shown in the second line, and the British ther-

FIG. 5.—NEW YORK CENTRAL 442 CLASS ATLANTIC TYPE

Total weight, 191,000 pounds

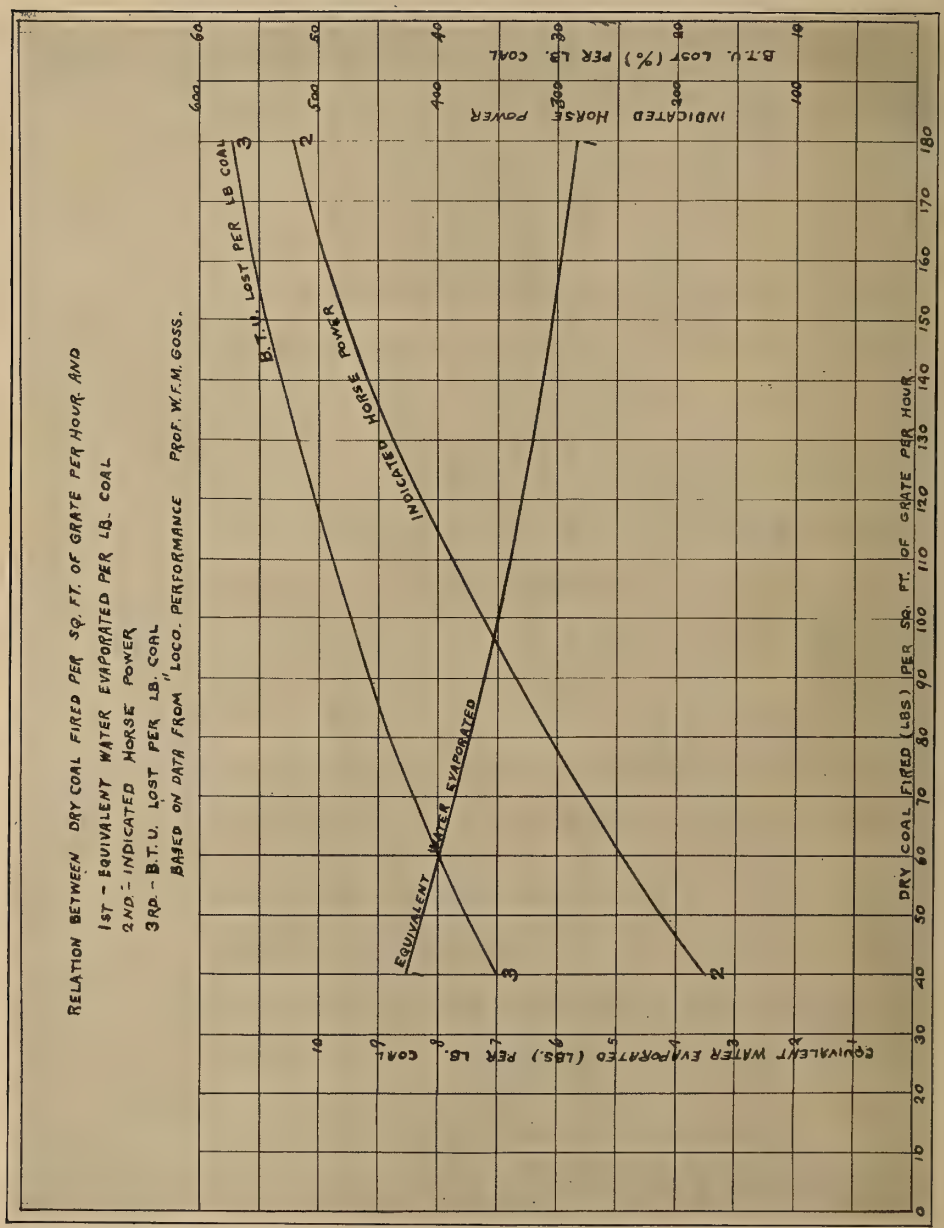

RELATION BETWEEN DRY COAL FIRED PER SQ. FT. OF GRATE PER HOUR AND
1ST - EQUIVALENT WATER EVAPORATED PER LB. COAL
2ND - INDICATED HORSE POWER
3RD - B.T.U. LOST PER LB. COAL
BASED ON DATA FROM "LOCO. PERFORMANCE" PROF. W.F.M. GOSS.
B.T.U. LOST (%) PER LB. COAL
INDICATED HORSE POWER
B.T.U. LOST PER LB COAL
INDICATED HORSE POWER
EQUIVALENT WATER EVAPORATED
EQUIVALENT WATER EVAPORATED (LBS.) PER LB. COAL
DRY COAL FIRED (LBS.) PER SQ. FT. OF GRATE PER HOUR.

FIG. C.—DATA OF LOCOMOTIVE PERFORMANCE

FIG. 6.—FLORIDA EAST COAST 462 CLASS PACIFIC TYPE LOCOMOTIVE

Total weight, 196,000 pounds

mal units lost per pound of coal are shown in the third. This latter line shows a loss of 35 per cent. when 40 pounds of coal are fired and 57 per cent. when 180 pounds of coal are fired.

The obvious conclusion to be drawn from the foregoing, and as emphasized by Dr. Goss, is that considerable economy can be effected in locomotive design by the use of larger boilers; so that, assuming the factor of adhesion is not too high and other things being equal, it is impossible to overdo the matter and make the boilers too large, provided the grate area is proportional to suit the kind of fuel used.

One of the most interesting things which is shown by comparing locomotives of to-day with those built in the past is that the boiler capacity is being very much increased over what was thought ample and sufficient a few years ago. It is, of course, much easier to provide sufficient boiler capacity on very heavy locomotives than it is on light ones, partly because there are a number of details which make up the complete locomotive that do not increase proportionately in weight, so that the general proposition is that the heavier the locomotive the larger its relative steam-making capacity.

The locomotive, compared with a stationary engine, is a fairly efficient machine, especially when working well within its capacity or at something below its maximum power, and a number of careful tests show that a horse-power-hour can be produced with coal of good quality from 3½ to 4 pounds, and in some cases as low as 3 pounds, for simple engines using saturated steam. For average coal under ordinary conditions 4 pounds is a fair average; but when the boiler is driven to its extreme capacity the efficiency is very much decreased on account of the strong draft required, greater spark losses and the incomplete combustion in the firebox, because of the enormous quantity of coal burned and the insufficient space for the complete combustion of the gases. So noticeable is this that 5 pounds, and in some cases 6 pounds of coal, are required per horse-power-hour when the boiler is forced to its extreme limits.

The Master Mechanics' Association committee on compound locomotives in the 1908 report stated, in their opinion, that one of the reasons for the economy of the compounds was due to the greater efficiency of the boiler, because of less total water required for a given horse-power, and state: "The fact still remains, however, that with two boilers of exactly the same design, one equipped with simple cylinders and the other with compound cylinders and performing the same work, that economy will be realized; and it is due

not only to the better cylinder performance with the compound locomotive, but to the fact that the boiler and grate are not called upon for as large an output when compound cylinders are used as where the simple cylinders are used, and considering the amount of work performed to be the same in both cases."

Superheated steam, by reason of its lightness and because it partakes more of the characteristics of a permanent gas than saturated steam, offers great possibilities in locomotive construction, especially in high-speed passenger service. It is a conservative statement that a horse-power-hour, which now requires about 4 pounds of coal for saturated steam, can be produced by highly superheated steam with 3¼ pounds of coal. Also, that the same results can be obtained with 20.7 pounds of water where 27 pounds are required with saturated steam. The possibilities for increased boiler power for large engines, and for relieving the fireman of so much manual work, are at once apparent.

Assuming the saving in coal to be 20 per cent., it follows then that the same work can be done with superheated steam and 80 pounds of coal as saturated steam can do with 100 pounds of coal. Therefore, if these figures are accepted, the power of an engine using superheated steam and burning 100 pounds of coal could be increased 25 per cent.; so that a locomotive can be produced with the same axle loads and the same total weight which will produce 25 per cent. greater power, burning like amounts of fuel.

The lightness of superheated steam is of great value in high-speed passenger work, because abnormally large ports and valves are not required. Furthermore, the elastic force of the steam, on account of the absence of cylinder condensation, is much better maintained and the losses due to this cause are largely obviated.

A locomotive having the fewest number of moving parts, other things being equal, is undoubtedly the best proposition for American railroads. The simplest machine which will do efficient work is the most satisfactory, and until the possibilities of the two-cylinder simple locomotive using superheated steam are exhausted it is probable that railroad managers and mechanical officers will not favourably consider increased complication without largely increased results. Demands for efficient maintenance, together with the enormous mileage required from American engines, are such as to direct attention to the simplest and least complex proposition, especially when complication involves the use of moving parts, which in many cases require

FIG. 8.—NEW YORK CENTRAL 442 CLASS ATLANTIC TYPE LOCOMOTIVE

Total weight, 200,000 pounds

to be kept steam-tight and in perfect working condition.

The problem that confronts us today consists in a great measure in building and operating locomotives which will produce, within the narrow limitations of weight permissible on moderate and first-class track, the greatest possible power with the least expenditure of fuel and water and with the lowest cost of repairs and maintenance. It would appear, therefore, from the results which have been obtained, that it is a conservative statement to say that locomotives are now being built, and will be built more extensively in the future, of largely increased horse-power without greater expenditure of fuel and within the present limitations of weight.

For further increase of weight of the ordinary type of Pacific engines it is necessary to consider the dynamic driving-wheel loads of locomotives with large drivers running, say, at 85 miles per hour. With the ordinary counterbalancing necessary to neutralize the horizontal movement of the reciprocating parts, it is necessary to balance the driving wheels, using from 50 to 60 per cent. of the weight of these moving parts. While this makes a smooth-running engine, it introduces vertical disturbances, which reach their maximum and minimum at each revolution, greatly increasing and decreasing the static load on the driving wheels. It is, therefore, clear that, considered from this standpoint, the balanced locomotive, in which the counterweights and reciprocating disturbance are reduced to a minimum, presents some very attractive features, and it seems probable that in the future engines of this type will be used to a greater extent for fast passenger service when their advantages are fully appreciated and understood. Many compound locomotives of this description have already been built and are running in this country which are performing satisfactory service.

There is one drawback, however,

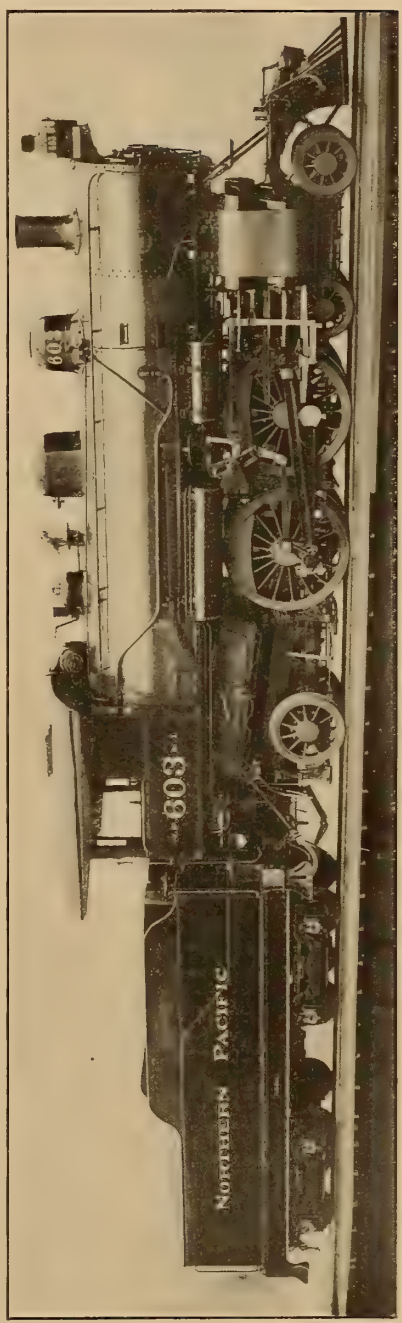


FIG. 7.—NORTHERN PACIFIC 442 CLASS ATLANTIC TYPE ENGINE
Total weight, 197,000 pounds

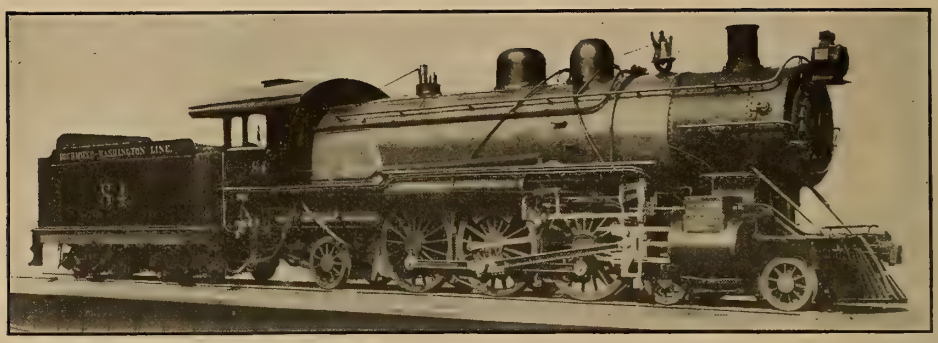


FIG. 9.—RICHMOND, FREDERICKSBURG & POTOMAC 462 CLASS PACIFIC TYPE LOCOMOTIVE
Total weight, 200,800 pounds

to the use of compound engines in high-speed passenger service, namely, the decreased efficiency at very high piston speeds, and this in a general way is characteristic of all compound engines.

Compounding is introduced in steam engineering principally to reduce cylinder condensation and to avoid the great range of temperatures which must necessarily occur when the steam is expanded in only one cylinder. Careful tests made upon compound engines show their greatest efficiency at full loads and at moderate speeds, and for this reason it would seem that three or four-cylinder simple locomotives using superheated steam possess many advantages for this service, and that but little saving, or at least only sufficient to overcome the complication in moving parts, is effected when compounding is added. The lightness of the superheated steam, its freedom, when sufficiently heated, from cylinder condensation, its economy in coal and water, present very attractive features for use in combination with a multiple cylinder locomotive.

It would, therefore, seem reasonable to suppose that the possibilities of the Pacific type over and above those illustrated and described are not yet reached, and can be very largely added to without exceeding the limits of wheel loads.

In Fig. D is shown a series of curves illustrating the decrease of tractive power of a passenger locomotive at various speeds. Curve No. 1 gives the maximum tractive power of a 21½ x 26-inch Atlantic engine

FIG. 10.—ROCK ISLAND 442 CLASS BALANCED ATLANTIC TYPE
Total weight, 202,000 pounds

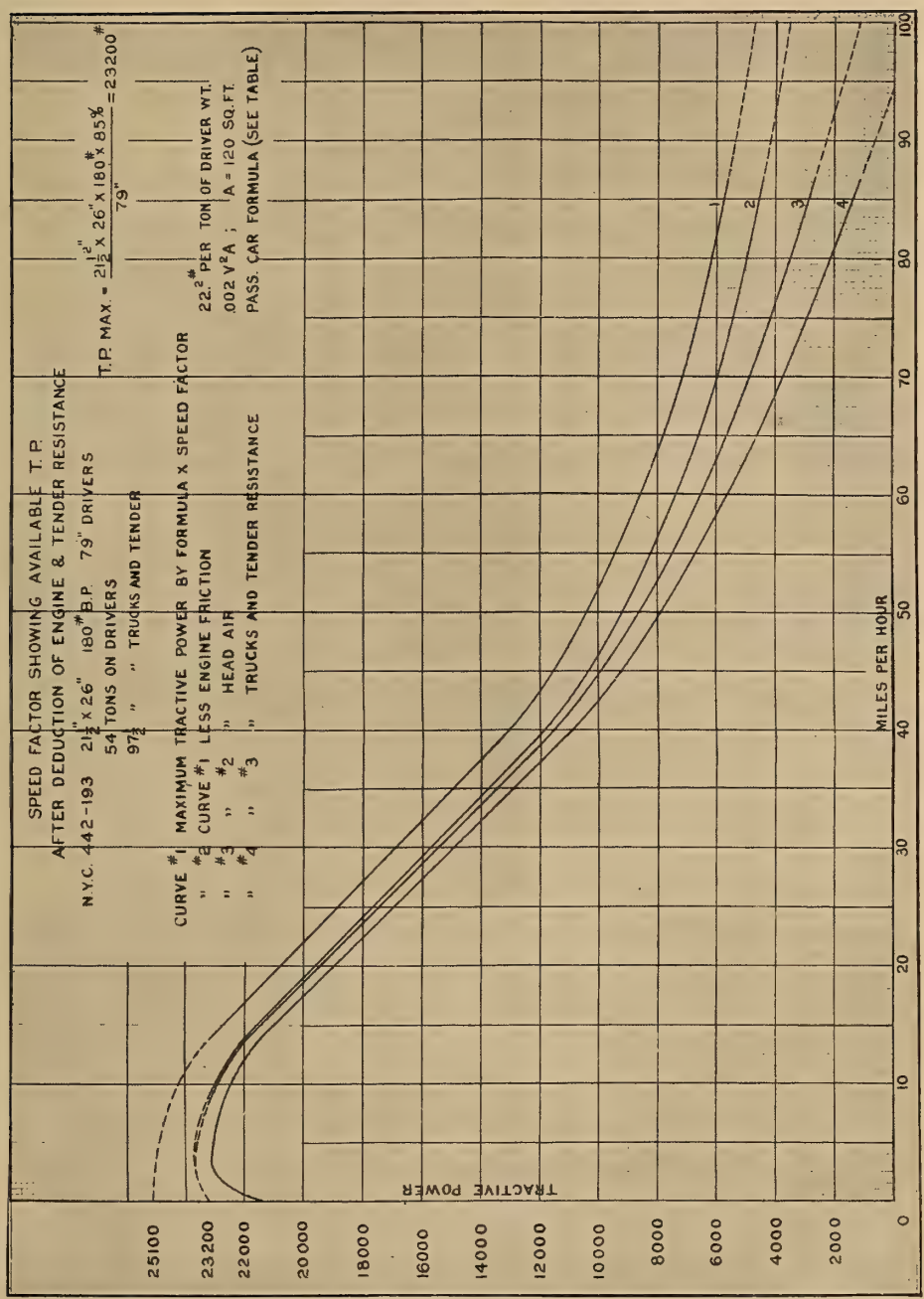


FIG. D.—LOCOMOTIVE SPEED FACTORS AND TRACTIVE POWERS

FIG. 11.—PHILADELPHIA & READING 442 CLASS ATLANTIC TYPE

Total weight, 205,400 pounds

weighing 191,000 pounds, with 108,000 on drivers, 180 pounds boiler pressure and 79-inch driving wheels.

Curve No. 2 shows the maximum tractive power, less engine friction.

Curve No. 3 shows the maximum tractive power, less engine friction and head air resistance.

Curve No. 4 shows the maximum tractive power, less engine friction, head air resistance, trucks and tender resistance.

The last curve represents the available tractive power to haul trains after the energy required to move the locomotive and tender is deducted.

It is interesting to note that at high speeds the amount of available tractive power on level track, unless assisted by slightly descending grades, for the movement of trains is comparatively small:

At 60 miles per hour, 5,600; at 70 miles per hour, 3,700; at 80 miles per hour, 2,200.

At approximately 94 miles per hour the entire energy of the locomotive on a straight, level track is absorbed in moving itself and tender.

The advantages of balanced engines to reduce the so-called "hammer blow" on the track, or, expressed in another way, to reduce to a minimum the increase in dynamic wheel loading at high speeds over the

FIG. 12.—PHILADELPHIA & READING 442 CLASS ATLANTIC TYPE

Total weight, 209,400 pounds

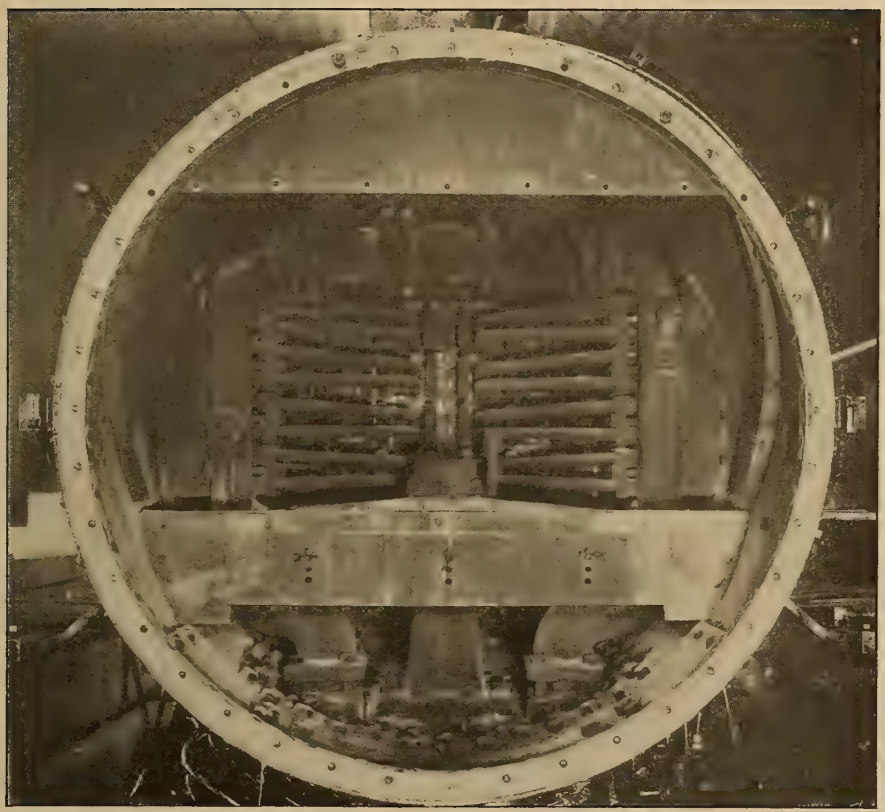


FIG. E.—SMOKE-BOX VIEW OF THE COLE SIDE-HEADER SUPERHEATER. AMERICAN LOCOMOTIVE COMPANY, SCHENECTADY

static driving-wheel loads, are too well known at the present time and have been discussed so often in the technical papers as to not require much elaboration in this paper.

An interesting type of this class is shown in Fig. 10, Atlantic 442 class balanced Rock Island No. 1040. Two engines of this design having four equal sized cylinders of 17½ inches diameter were designed under Mr. W. A. Nettleton's direction for passenger service. The cylinders are of the single-expansion type, and the boiler is supplied with the Cole side header superheater (Fig. E), designed for the use of highly superheated steam. It will be noticed that the power of the four cylinders is applied to the front cranked driving axle. The valve motion is Walschaert, and the steam is distributed to both cylinders on each side by means of double valves on one stem.

Calculations show that the vertical disturbance of these engines, due to centrifugal force of excess weights to neutralize the action of reciprocating parts, is reduced to a minimum. At 85 miles per hour the static load of 29,000 pounds on each driving wheel is increased by 7,950 to 36,950 and decreased the same amount to 22,220 pounds at each revolution, a difference of 27.5 per cent. The combined static axle load of 58,000 pounds is only increased 975 pounds, to a maximum of 58,975, and decreased to a minimum of 57,025 pounds during each revolution, a difference of only 1.68 per cent. The reason that the variation of the total axle load is less than individual wheels is due to the fact that the

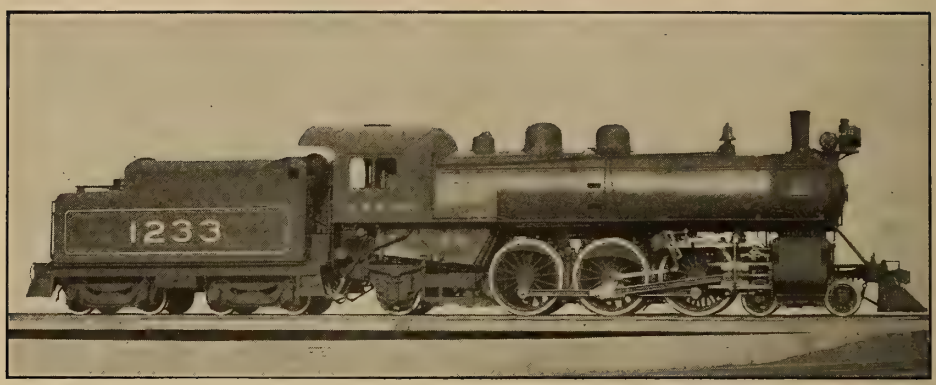


FIG. 13.—CANADIAN PACIFIC RAILWAY 462 CLASS PACIFIC TYPE

Total weight, 218,000 pounds

counterbalance weights for nosing are located almost opposite to each other on the right and left-hand wheels, so that the disturbing influence is practically neutralized.

Compared with a two-cylinder engine of the unbalanced type, but with 79-inch in place of 73-inch wheels at the same speed, namely, 85 miles per hour, the following figures show the relation:

Static weight on each driving wheel, 26,450 pounds; centrifugal force of excess balance in driving wheels for 50 per cent. of the reciprocating weight, 16,100 pounds, making the dynamic load 42,550 pounds and decreasing it to 10,350 at each revolution, a difference of 61 per cent. Considering the combined static weight on one axle of 52,900 pounds, the centrifugal force equals 22,760 pounds, increasing the dynamic axle load to 75,660 and decreasing it to 30,140 pounds at each revolution, an increase of 43 per cent.

The advantages of the balanced type to permit greater wheel loads when running at high velocities is, therefore, apparent without further comment.

It is interesting to consider what possibilities are afforded in other designs of passenger engines after the limits of the "Pacific" 462 class are reached. An increase of tractive power means greater weight on driving wheels, and this, in turn, requires (if 60,000 pounds is accepted as the maximum axle load) that the

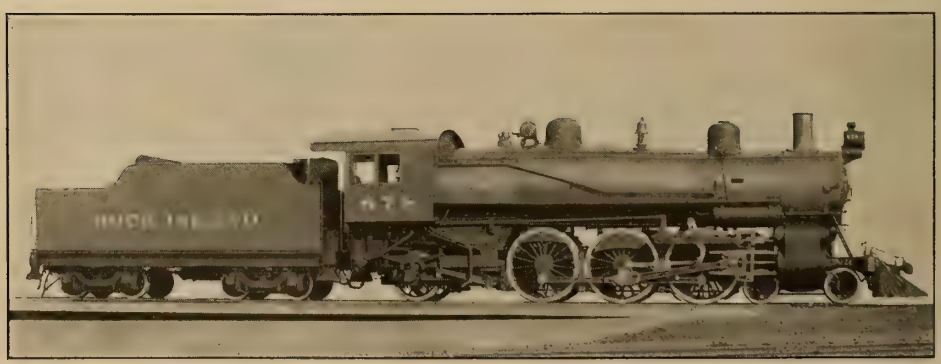


FIG. 14.—CHICAGO, ROCK ISLAND & PACIFIC RAILWAY 462 CLASS PACIFIC TYPE

Total weight, 226,000 pounds

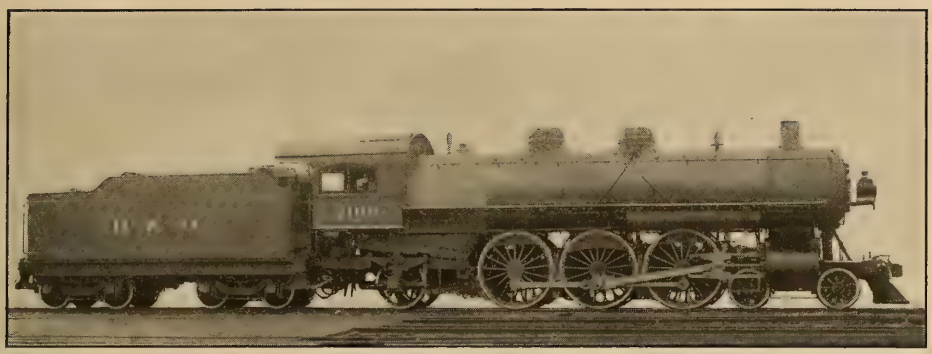


FIG. 15.—BALTIMORE & OHIO 462 CLASS PACIFIC TYPE
Total weight, 229,000 pounds

number of axles should be increased in order to increase the power much above the 462 class now in existence. pacity over the Pacific type than any other design, because from five to six pairs of driving axles can be used

FIG. 16.—NEW YORK, NEW HAVEN & HARTFORD 462 CLASS PACIFIC TYPE
Total weight, 229,500 pounds

At the present time the Mallet articulated locomotive seems to offer more advantages for increased ca- without resulting in excessively long rigid wheel bases, which would be prohibited in passing curves of even

FIG. 17.—ERIE 462 CLASS PACIFIC TYPE
Total weight, 230,500 pounds

Number	1	2	3	4	5	6	7	8
Name of railroad	B. & M.	B. & M.	P. R. R.	C. & N. W.	N. Y. C.	F. E. C.	N. P.	N. Y. C.
Builder	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	B. L. W.	A. L. Co.
Class	460	442	442	442	442	462	442	442
Weight on leading truck, pounds	41,000	42,000	31,500	43,000	42,500	38,000	51,950	50,000
Weight on driving wheels, pounds	130,000	90,000	111,000	96,000	105,800	122,500	100,800	110,000
Weight on trailing truck, pounds	.....	43,000	35,500	41,000	42,700	35,500	44,300	40,000
Weight total of engine, pounds	171,000	175,000	178,000	180,000	191,000	196,000	197,050	200,000
Weight of tender, pounds	110,600	115,500	133,000	143,700	132,600	123,600	122,950	122,000
Cylinder, diameter and stroke, inches	20 x 26	19 x 28	20½ x 26	20 x 26	21½ x 26	20 x 26	21 x 26	†15½ & 26x26
Valves, type	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston
Wheels, diameter of driving, inches	72	79	80	81	79	68	73	79
Boiler pressure, pounds	200	200	205	200	180	200	185	220
Boiler, type	Wagon Top	Straight	Belpaire	Straight	Straight	Straight	Straight	Straight
Boiler outside diameter front end inches	66⅜	66¼	67	68⅜	72	—62	72⅛	72
Firebox, length, inches	102	92	111	102	96	96	96	96
Firebox, width, inches	65¼	65	72	65	75	70	65¼	75
Tubes, number	320	326	315	331	375	250	196 22	300
Tubes, outside diameter, inches	2	2	2	2	2	2	2 5⅜	2
Tubes, length	15 ft. ½ in.	16 ft. 0 ins.	15 ft. 1 in.	16 ft. 0 ins.	16 ft. 0 ins.	18 ft. 6 ins.	16 ft. 0 ins.	16 ft. 0 ins.
Heating surface, tubes, square feet	2,631	2,717	2,474	2,758	3,123	2,411	2,112	3,248
Heating surface, firebox square feet	160	152	166	173	175	160	173	175
Heating surface, total square feet	2,791	2,895	2,640	2,955	3,321	2,571	2,285	3,446
Grate area, square feet	46.1	41.75	55.5	46.3	50.3	46.8	43.5	50.3
Tractive power, maximum, pounds	24,600	21,800	23,800	21,800	23,300	26,000	24,700	23,500
Cylinder horse-power	1,332	1,202	1,435	1,332	1,388	1,332	1,360	1,629
Total weight of engine ÷ horse-power	128	145	124	135.1	137	147	145	122
Heating surface ÷ cylinder volume	580	631	500	625	514	544	420	.....
Heating surface ÷ horse-power	2.1	2.41	1.72	2.22	1.82	1.93	1.68	2.11
Total coal = horse-power × 4	5,328	4,808	5,740	5,328	6,880	5,328	*4,420	*†5,740
Total coal ÷ grate surface	115	115	103	115	157	114	101	114
Volume one cylinder, cubic feet	4.73	4.59	4.96	4.73	5.2	4.73	5.2	...

* Total coal = horse-power × 3¼. † Four cylinders. *† At 3.52.

Number	9	10	11	12	13	14	15	16
Name of railroad	R. F. & P.	C. R. I. & P.	P. & R.	P. & R.	C. P.	C. R. I. & P.	B. & O.	N.Y.,N.H.& H
Builder	B. L. W.	A. L. Co.	P. & R. Shops	P. & R. Shops	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.
Class	462	442	442	442	462	462	462	462
Weight on leading truck, pounds	46,850	49,000	50,100	49,300	47,500	40,000	40,500	46,000
Weight on driving wheels, pounds	143,750	116,000	112,000	110,300	136,000	148,500	150,500	142,500
Weight on trailing truck, pounds	40,200	37,000	49,150	49,800	34,500	37,500	38,500	41,000
Weight total of engine, pounds	200,800	202,000	205,400	209,400	218,000	226,000	229,500	229,500
Weight of tender, pounds	120,200	149,900	150,000	160,000	131,500	144,700	140,300	134,000
Cylinder, diameter and stroke, inches	22 x 28	†17½ x 26	‡ 18½ x 24	22 x 26	21 x 28	23 x 28	22 x 28	23 x 28
Valves, type	Slide	Piston	Piston	Slide	Piston	Piston	Piston	Slide
Wheels, diameter of driving, inches	73	73	80	86	69	73	74	73
Boiler pressure, pounds	200	160	200	235	200	185	200	200
Boiler, type	Straight	Wagon Top	Straight	Straight	Wagon Top	Wagon Top	Straight	Straight
Boiler outside diameter front end inches	74	68⅛	65	66	67⅜	67	72	70
Firebox, length, inches	108	102	120	126	94	108	108	108
Firebox, width, inches	66	60	108	108	70	60	75¼	71
Tubes, number	318	206 24	307 11	349	193 22	328	276	310
Tubes, outside diameter, inches	2¼	2 5¼	2 3	2	2¼ 5	2	2¼	2¼
Tubes, length	21 ft. 0 ins.	18 ft. 0 ins.	12 ft. 0 ins.	16 ft. 6 ins.	19 ft. 6 ins.	19 ft. 9 ins.	20 ft. 0 ins.	20 ft. 6 ins.
Heating surface, tubes, square feet	3,917	2,521	2,029	2,996	2,765	3,375	3,235	3,729
Heating surface, firebox square feet	190	195	260	274	186	202	183	189
Heating surface, total square feet	4,107	2,716	2,289	3,270	2,951	3,577	3,418	3,948
Grate area, square feet	49.5	42.8	90	94.5	45.6	45.2	56.5	53.4
Tractive power, maximum, pounds	31,100	27,800	26,182	29,229	30,400	31,900	31,100	31,600
Cylinder horse-power	1,614	1,630	1,710	1,896	1,470	1,630	1,614	1,614
Total weight of engine ÷ horse-power	124	124	120	110	148	139	142	142
Heating surface ÷ cylinder volume	667	375	409	572	527	538	554	641
Heating surface ÷ horse-power	2.45	1.67	1.34	1.72	2.01	2.2	2.12	2.45
Total coal = horse-power × 4	6,456	*5,310	*5,560	7,584	*4,780	6,520	6,456	6,456
Total coal ÷ grate surface	130	124	62	80	105	144	114	121
Volume one cylinder, cubic feet	6.16	(2 ×) 3.62	(1½ ×) 3.74	5.72	5.6	6.64	6.16	6.64

* Total coal = horse-power × 3½. † Four cylinders. ‡ Three cylinders.

Number	17	18	19	20	21	22	23	24
Name of railroad	Erie	C. B. & Q.	N. Y. C.	N. Y. C.	C. & N. W.	N. Y. C.	P. R. R.	A. T. & S. F.
Builder	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	A. L. Co.	B. L. W.
Class	462	462	462	262	462	462	462	4462
Weight on leading truck, pounds	41,000	39,000	42,000	27,700	50,000	46,000	48 000	58,050
Weight on driving wheels, pounds	149,000	157,000	151,000	170,000	151,000	171,500	176,500	268,000
Weight on trailing truck, pounds	40,500	38,000	46,000	47,000	44,000	48,500	45,500	50,400
Weight total of engine, pounds	230,500	234,000	239,000	244,700	245,000	266,000	270,000	376,450
Weight of tender, pounds	162,800	152,900	149,700	159,000	154,100	162,700	144,350	223,550
Cylinder, diameter and stroke, inches.	22½ x 26	22 x 28	22 x 26	21½ x 28	23 x 28	22 x 28	24 x 26	†24&38x28
Valves, type	Piston	Piston	Piston	Piston	Piston	Piston	Piston	Piston
Wheels, diameter of driving, inches	74	70	75	79	75	79	80	73
Boiler pressure, pounds	200	200	200	200	190	200	210	200
Boiler, type	Straight	Wagon Top	Straight	Wagon Top	Wagon Top	Straight	Straight	Straight
Boiler outside diameter front end inches	75	70	72	70	70¼	72	80	72
Firebox, length, inches	108	108	108	108	108	108	110	119⅜
Firebox, width, inches	75	72	75	73	70¼	75	80	63¼
Tubes, number	195	291	394	322	396	382	343	294
Tubes, outside diameter, inches	2¼	2¼	2	2¼	2	2	2¼	2¼
Tubes, length	20 ft. 0 ins.	21 ft. 0 ins.	21 ft. 0 ins.	19 ft. 6 ins.	20 ft. 0 ins.	20 ft. 0 ins.	21 ft. 0 ins.	19 ft. 0 ins.
Heating surface, tubes, square feet	3,119	3,585	4,314	3,678	4,130	3,982	4,222	3,275
Heating surface, firebox square feet	202	198	208	198	206	213	205	202
Heating surface, total square feet	3,322	3,783	4,548	3,905	4,364	4,242	4,427	3,477
Grate area, square feet	56.5	54.3	56.5	55	52.7	56.5	61.8	52.5
Tractive power, maximum, pounds	30,260	31,100	28,500	27,850	31,800	29,200	33,400	53,000
Cylinder horse-power	1,686	1,614	1,614	1,542	1,675	1,614	2,014	.....
Total weight of engine ÷ horse-power.	137	145	148	159	146	164	134	.....
Heating surface ÷ cylinder volume	555	614	795	664	658	690	652	.....
Heating surface ÷ horse-power	1.97	2.34	2.82	2.53	2.59	2.63	2.2	.....
Total coal = horse-power × 4	6,744	6,456	6,456	6,168	6,700	6,456	8,056	.....
Total coal ÷ grate surface	118	118	114	130	127	114	130	.....
Volume one cylinder, cubic feet	5.98	6.16	5.72	5.88	6.64	6.16	6.79	,,,,,

† Four cylinders.

FIG. 18.—CHICAGO, BURLINGTON & QUINCY 462 CLASS PACIFIC TYPE

Total weight, 234,000 pounds

moderate radius at high speed. The fact that the front engine of the Mallet locomotive is hinged to the rigid-back engine allows a flexibility not possible with other types, so that there are possibilities in this type permitting, perhaps, twice the horsepower of the Pacific type, as viewed from the standpoint of axle loads and track conditions. It would, therefore, appear that the limit of heavy passenger locomotives has not yet been reached, and that with improved methods, such as superheating, compounding, etc., or the use of oil fuel, the question of firing and obtaining steam pressure is well within the possibility of human endurance.

Locomotives have for years been built with the greatest height and width limitation which the clearance of roads in America will permit; but the third dimension, namely, length, is one which can be extended indefinitely, so that by the use of locomotives of flexible wheel base the length can be increased far beyond the ordinary types now in use; so that the only practical limitation which appears at the present time is the ability to deliver a sufficient amount of coal to generate steam.

The Boston & Maine locomotive shown in Fig. 1 is given to illustrate the ten-wheel 460 class for passenger service. These engines have 72-inch driving wheels and wide fireboxes. The first one was built in 1904, and at the present time there are thirty-four in service.

The results obtained from these engines in passenger service have been satisfactory; but they do not have the enormous steaming capacity

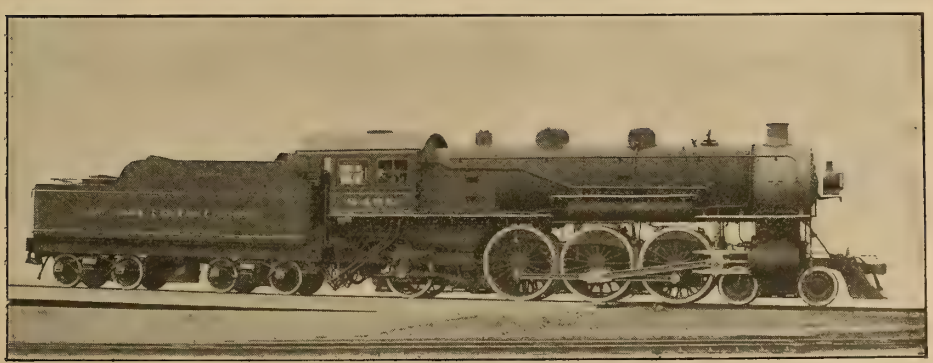


FIG. 19.—NEW YORK CENTRAL 462 CLASS PACIFIC TYPE

Total weight, 239,000 pounds

FIG. 20.—NEW YORK CENTRAL 262 CLASS PRAIRIE TYPE

Total weight, 244,700 pounds

of the Atlantic or Pacific type, on account of the necessary limitations imposed by the size of boiler and depth of firebox, because of its location over the top of the driving wheels.

The Atlantic 442 class, built for the Boston & Maine, Fig. 2, are noted as good steamers. The first lot, with Stephenson valve motion, were put into service in 1901. At the present time forty-one are running. The later engines have Walschaert valve gear, as shown in the illustration.

The Pennsylvania Railroad standard Atlantic engine, Class E-2-B, is shown in Fig. 3. It is practically the same as the E-2-A, except that it has piston instead of slide valves. These engines have 80-inch wheels, and run the 18-hour train from New York to Chicago. It is no unusual thing for the speed of this train between Crestline and Chicago to reach 85 to 90 miles per hour on slightly descending grades. On perfectly level straight track speeds of 82 miles an hour are recorded. On ascending grades of 0.11 per cent. straight track, speeds of 80 miles per hour have been reached. The approximate weight of the train is 720,000 pounds, or 522 tons, including engine and tender.

For a number of years fast passenger trains on the New York Central were hauled by Atlantic 442 class engines, as shown in Fig. 5. The first one of these engines was completed in 1900, and at the present time 233 are in service on the New York Central lines. It has proved to be an unusually successful design, and within its limitations of adhesive weight for starting heavy trains is unequaled for high-speed passenger work, on account of its very large boiler capacity. The ratios of heating surface, grate area, etc., for cylinder volume and horse-power are extremely good.

A design of moderate-weight Pacific 462 class is shown in Fig. 6 for the Florida East Coast Railway. This order has been repeated without change, so that it is a proof of its satisfactory service. At present sixteen are in service on the above road. It shows the possibilities of this type of engine for service where the track limitations require a medium weight and heavy wheel loads are not permissible.

The Atlantic engine shown in Fig. 8, No. 3,000, is a four-cylinder, balanced type, built in 1904 for the New York Central & Hudson River Railroad, and was exhibited and tested at the World's Fair at St. Louis.

The balancing of this engine proved to be practically perfect, as the "nosing" on the testing plant at speeds of 75 miles per hour was scarcely noticeable. The maximum

indicated horse-power developed by this engine was 1,641. The dynamometer horse-power was 1,475. A full account of the tests of this and other engines will be found in the report published by the Pennsylvania Railroad System in 1905.

The three-cylinder locomotive possesses some advantages in greater uniformity of turning moment or "torque," which permits the adhesive weight to be somewhat less than the ordinary two-cylinder type without undue slipping. The balancing of reciprocating parts is better than the two-cylinder, but not quite so good as the four-cylinder type. A single-throw crank axle is cheaper and probably better in construction than the two-throw of the two-cylinder engine. These advantages, while well known, have not been tried in this country on locomotives for at least twelve or fifteen years. The last the writer has knowledge of were built in 1893 for the Erie & Wyoming Valley for freight service.

The three-cylinder Atlantic 442 class engine shown in Fig. 11 was built and designed at the Reading shops, Reading, Pa., by Mr. H. D. Taylor, superintendent M. P. & R. E. The engine presents an attractive appearance, and is unusually well designed and finished. It was exhibited at the Master Mechanics' Association Convention at Atlantic City, June, 1909.

With a three-car train a speed of 106 miles per hour has been attained. The running time between two points 5 miles apart was 2 minutes and 50 seconds, or 34 seconds per mile. The engine is now in regular service on the New York Division of the Reading Railroad, and has run 26 miles in exactly 19 minutes. It has also maintained a speed of 82.1 miles per hour. The weight of train, including engine and tender, was 515 tons.

There are a few railroads in the East which use anthracite coal for locomotive fuel. The high-speed Atlantic 442 class locomotive built by the Reading Railroad is shown in Fig. 12, and is adapted for anthracite coal, the firebox having an area of 94.5 square feet. The driving wheels are of unusual size—86 inches in diameter. The best run made by one of these engines was on a regular train between Camden and Atlantic City, a distance of 55.6 miles. The run was made in exactly 41 minutes, equivalent to an average speed of 81.3 miles per hour. The total weight of train, including engine, tender and cars, was 605 tons. Engines of the same class have records of single miles in 36 seconds, or 100 miles per hour.

Such high speeds demand unusually fine track, as they are possible only with a combination of exceptionally good track, large driv-

FIG. 21.—CHICAGO & NORTHWESTERN 462 CLASS PACIFIC TYPE

Total weight, 245,000 pounds

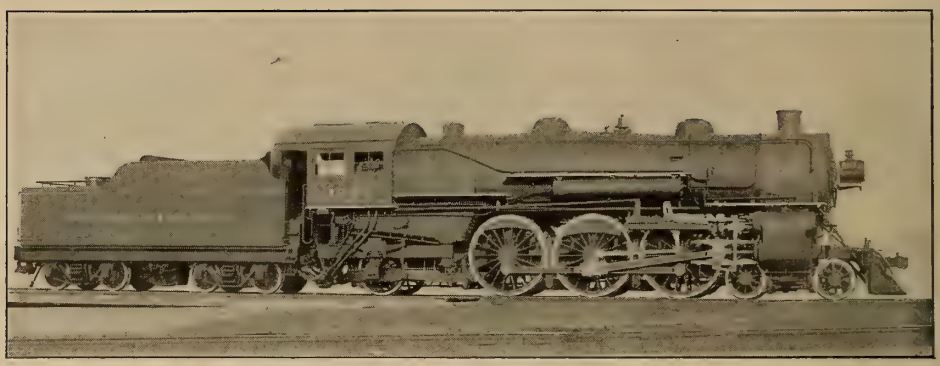


FIG. 22.—NEW YORK CENTRAL 462 CLASS PACIFIC TYPE

Total weight, 266,000 pounds

ing wheels and first-class machinery.

The standard Canadian Pacific 462 class, with Vaughan-Horsey superheater, is shown in Fig. 13. These engines were designed by Mr. H. H. Vaughan. They have proved to be very economical and efficient in heavy passenger service, and show a notable decrease in the consumption of fuel and water.

On the Chicago, Rock Island & Pacific their through passenger trains are hauled by Pacific 462 class engines, as shown in Fig. 14. Thirty-three of the engines illustrated were constructed in March and April, 1909. They have proved to be very powerful, satisfactory and efficient engines, and careful tests show that they are very economical in fuel and water.

In all, this road has eighty-three Pacific type engines running; but the later engines are considerably heavier and with driving wheels and cylinders of increased diameter. They were designed under the direction of Mr. W. A. Nettleton, general superintendent of motive power.

In order to haul the heavy passenger trains on time on the Baltimore & Ohio Railroad, the Pacific 462 class, shown in Fig. 15, was designed under Mr. J. H. Muhlfeld's direction. Thirty-five of these engines were built at the Schenectady Works in 1906. These engines have fully realized the confidence of the railroad company and the builders in the selection of this class.

In order to haul its heavy through fast passenger trains between New

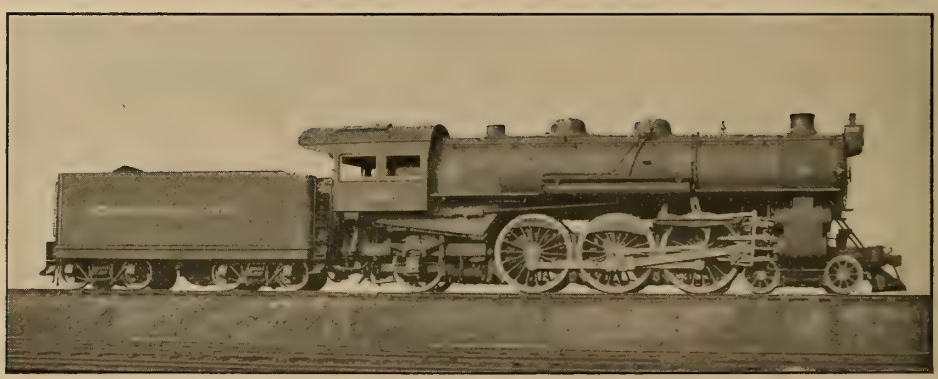


FIG. 23.—PENNSYLVANIA 462 CLASS PACIFIC TYPE

Total weight, 270,000 pounds

York and Boston, the New York, New Haven & Hartford Railroad selected the Pacific 462 class as the most suitable for this work. These engines are illustrated in Fig. 16. Owing to their large tractive power, ahhesive weight and steaming capacity, they are capable of starting and keeping on schedule time the heaviest trains run on this railroad.

Owing to the hilly country through which the Erie Railroad passes, it was found necessary three or four years ago to use heavier passenger locomotives, and the Pacific 462 class, shown in Fig. 17, was designed for this purpose. The first one of these engines was built in April, 1905. Forty-three are now in service. They have shown themselves to be remarkably free steaming and economical engines, and from the fact that the design has been duplicated three or four times without any material change, it shows how suitable the engines are for the work they have to perform.

The Pacific 462 class shown in Fig. 18, is used by the Chicago, Burlington & Quincy for hauling their large passenger trains. A large number of these engines are now in service, and have given extremely satisfactory results.

The Pacific 462 class shown in in Fig. 19 is a medium-weight engine, a number of which are operated on the Michigan Central. Others of this class, similar except for a few changes, have been running on the New York Central lines for the past four or five years; but in the engine illustrated there is an unusual amount of heating surface obtained, on account of the flues being one foot longer and more closely spaced than on others of the same class. These engines haul the heaviest fast passenger trains on the Michigan Central, and are remarkably free steamers.

The Prairie 262 class locomotives have been used to a considerable extent in fast passenger service. One of the heaviest of these engines is shown in Fig. 20. A number of these engines were built for the Lake Shore and they hold records of speed equal to any of the Pacific class.

After using the Atlantic 442 class for nine years on all their heavy fast passenger trains, the Chicago & Northwestern officials decided this year that the weight of some of their passenger trains had increased so much that there was hardly sufficient margin of power in these engines to start the trains and keep them on schedule. The Pacific 462 class, Fig. 21, was decided upon. Twenty-five of these engines were completed in the fall of 1909, and at the present time are being broken in prior to being put on the heaviest trains. On account of their great tractive power and boiler capacity, they will no doubt realize in actual

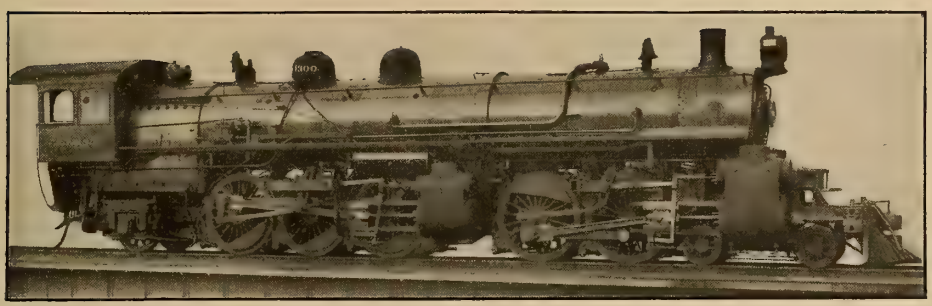


FIG. 24.—ATCHISON, TOPEKA & SANTA FE 4462 CLASS ARTICULATED TYPE

Total weight, 376,450 pounds

service all that is expected of them.

The New York Central lines standard heavy Pacific class engine is shown in Fig. 22. These engines haul the fast passenger trains on the New York Central lines between New York and Chicago, which often reach a very high speed, especially when it is necessary to make up time if unusual detentions have occurred. Usually the fastest running is on the straight, level portion of the Lake Shore between Elkhart and Toledo, a distance of 133.4 miles. In one instance the run was made from start to stop in 110 minutes, and in another in 114 minutes, the average speed being 72.8 and 70.2 miles per hour. The approximate weight of the train back of tender was 315 tons; including engine and tender, 529 tons. In order to make this record, the maximum running speed for short distances was between stations about 85 miles per hour.

The Pacific 462 class engine No. 7,067, shown in Fig. 23, was built in 1907 at the Pittsburg works of the American Locomotive Company for heavy fast passenger service west of Pittsburg for the P. L. W. of P. At the time of its construction it was the heaviest locomotive of its class ever constructed, and its weight has not yet been exceeded.

The engine was designed under the direction and to meet the views of Mr. D. F. Crawford, general superintendent of motive power, and its performance in handling very heavy fast passenger trains has, in some cases, exceeded the most sanguine expectations.

The largest passenger locomotive is illustrated in Fig. 24. One was built by the Baldwin Locomotive Works in October, 1909, for the Atchison, Topeka & Santa Fe Railroad of the 4462 Mallet articulated class. The total weight in working order is 376,450 pounds, with 268,000 pounds on driving wheels. The tractive power is 53,000 pounds. It was designed for fuel oil, equipped with superheater, re-heater, combustion chamber, feed-water heater, and Jacobs-Schupert sectional firebox.

General conclusions regarding modern high-speed passenger locomotives derived from the information set forth in this paper:

Increased boiler capacity is one of the most prominent characteristics.

Increased grate area, limiting the fuel burned per square foot per hour to approximately 120 pounds for bituminous coal.

The use of Atlantic and Pacific engines has enabled the boiler capacity to be largely increased over the eight and ten-wheel types.

Dynamic wheel and axle loads may be very much decreased by the use of crank axles and opposed reciprocating parts.

Superheating affords a convenient and practical method of increasing the boiler capacity because of its lower specific heat and the elimination of cylinder condensation, which permits of the use of larger cylinders and makes for economy of the use of steam.

After the possibilities of the Pacific type are reached in combination with the fuel-saving devices, such as superheating or greatest decreased dynamic driving-wheel or axle loads possible by crank axles and the consequent balancing of reciprocating parts, the Mallet articulated type affords possibilities of increased power by reason of the greater number of driving axles which can be conveniently used without unduly increasing the rigid driving wheel base.

Considerable fuel saving can be effected by increased size and capacity of boilers, permissible by careful designing of details. Any reduction in weight by improved design or better material affords possibilities in increase of boiler, so that the fuel is consumed under more economical conditions.

NOTE.—The numbers heading the columns in the tables on pages 402, 403 and 404 correspond to the numbers of the illustrations, and give very fully the data concerning each locomotive.

DEFLECTION TESTS OF RAILWAY BRIDGES

By Conrad Gribbie, A. M. I. C. E.

THE value of deflection tests of railway bridges depends as much on the way in which the results obtained are used as on the care and judgment with which they are measured. Various opinions are held as to their value, and wonderful theories are based on the results of the tests. It is extraordinary how much store is set by a low reading of deflection obtained from a newly-built girder, and if the reading is considerably less than one-twelve-hundredth of the span—a sacred proportion in some eyes—the girder is considered eminently satisfactory.

Of course, there is nothing particularly desirable in the fact that a girder deflects only one-twelve-hundredth of its span under ordinary working loads. If it is a very deep one it should not deflect so much, and, if shallow, it may be quite unnecessarily understressed if it does not deflect much more. If the span, however, be exactly eight times the depth of the girder and the allowable stress in mild steel be taken as 6½ tons per square inch, then the deflection will be about one-twelve-hundredth of the span.

If the calculations for the strength of the girder have been correctly made and the girder has been carefully and well built, no deflection tests are necessary.

If it is desired to check the workmanship by a deflection test, then only one test is possible, and that is the measurement of the permanent set of this girder when it is first loaded after it has been erected and relieved of intermediate supports. Loose rivets badly butting flange and web plates tend to cause the girder to sag from its true camber line; but this sag can never be taken out, and it is a permanent set. After this no further tests will reveal any defects in workmanship, though the deflection may be an index of the stresses in the girder under different loads.

In the case of girders which are in use, it is possible by means of deflection tests to determine the conditions under which they are stressed by different loads. Such tests must, however, be combined with a very careful examination of the girder, and, in most cases, with rather lengthy calculations.

It is the practice of the inspecting officer of the Board of Trade to measure the deflection of new girders in railway bridges before he sanctions the opening of the line for traffic. He is also furnished with complete drawings of the bridge and with certain particulars as to loads coming upon it and as to the estimated stresses caused by them. What deductions he makes from the deflection readings obtained one does not know. When the calculations show ample margin of strength to meet all possible loads, deflection tests are quite unnecessary.

It is, moreover, not true that the deflection of a girder under a certain load indicates invariably and accurately the stress in the girder or that it bears any fixed proportion to it.

For example, take the case of a cast-iron bridge. One girder out of, perhaps, four which are similarly loaded may have a serious internal flaw, the existence of which is not suspected. Another may have a couple of bolt holes at the centre of

the lower flange. The remaining two may be perfect throughout. On measuring the deflections of the four girders under equal loads the readings obtained will be as nearly equal as possible. The extra deflection due to the local flaw or to the bolt holes will not be measurable by ordinary means.

The stresses in the girders may be very different. The one with the unseen flaw will, for want of knowledge, be assumed to be as perfect as the last two. The one with the bolt holes will be considered to be the most highly stressed of the four, and by making proper allowance for the holes the stress can be as accurately ascertained as the stress in the two perfect ones. The deflection test has, therefore, failed to reveal the weakness of the two imperfect girders.

Suppose, however, the imperfect girder had such a serious succession of flaws that its deflection was perceptibly greater than that of the others. Then we should be equally unable to ascertain the stress, since we do not know the shape of its effective section nor how many and how great the suspected flaws are.

In fact, to deduce stress from deflection one must know the moment of inertia of the section of the girder not only at the centre, but at every point in the length of the girder.

Now take the case of an ordinary riveted plate girder or trough girder. Suppose an error in construction has been made and two flange plates on the tension flange are jointed together instead of having sufficient lap, then the stress at this point inflicted on the remaining plates and the cover plate, if any, will be increased. Possibly there may be an uncovered joint in the main angles concealed by a web stiffener, or, again, the rivet holes may, at one point only, be arranged in a direct line transversely to the girder instead of being in a zig-zag arrangement. None of these causes will affect the deflection reading by any amount that can be measured, but the stress in the weakened flange will certainly be raised by a calculable amount; no "rule of thumb" formula will serve to deduce the maximum stress in the girder from deflection readings in these cases, for the simple reason that the strength of the girder is the strength of its weakest part, whereas the deflection of the girder depends on the strong portions as much as on the weak portions, and is affected by every portion and section of the girder to a certain proportional degree.

Therefore, it may be asked, What is the use of any deflection tests at all? The answer to this question is that great use may be made of them if they are not required to reveal what they are not able or adapted to reveal. Since in any girder the strength is the strength of its weakest part, it is necessary to discover where the weakest part is in order to ascertain the greatest stress. This is done by inspection and calculation before any tests take place. If the girder is perfectly designed, there will be no weakest part, but the flange stress throughout will be uniform. Practically, this is an impossibility; in every girder there is a point where the bending moment is zero; here the flange area should be *nil* or else the girder is not uniformly strong. Since there must always be some flange area, the girder must have a weaker part than that where the bending moment is zero. Further, in riveted girders the stress is greater in sections of the girder in which rivet holes occur than in sections through undrilled plates. The deflection reading will, however, be as much affected by the strength of those portions of the girder between the rivet holes as by the strength of the weaker sections. It is necessary, therefore, to calculate the moment of resistance of the girder at sections throughout its length if it is not of perfectly uniform section.

In the case of a plain rolled steel beam there is only one moment of in-

ertia to be calculated for both stress and deflection. Here the girder is perfectly uniform, and the weakest part is at the point where the bending moment is greatest, which will occur at or near the centre in the case of a girder freely supported at its ends. The deflection here for a load uniformly spread over the girder is $\frac{5}{384} \frac{WL^3}{EI}$, where L is the span, W the total load, E the modulus of electricity of the material, and I the moment of inertia of the section.

The stress at the centre is $\frac{WLY}{8I}$, where Y is the distance of the extreme fibres from the neutral axis and equals in a symmetrical section half the depth, or $\frac{D}{2}$.

Let Δ be the deflection and F the stress, then from the above expressions $F = \Delta \times \frac{24}{5} \frac{ED}{L^2}$.

Now if F is to equal 6.5 tons per square inch, and $\Delta = \frac{L}{1{,}200}$, and E = 13,000 tons per square inch, then $\frac{L}{D} = 8$, showing that for girders of uniform section the ratio of span to depth to satisfy the above conditions should be 8 to 1. Since there is no reason rigidly to adhere to such a ratio of span and depth, whereas the working stress on a given material should be approximately uniform, therefore any fixed proportion of deflection to span is unnecessary, so long as practical reasons do not render a particular amount of deflection desirable or otherwise.

Now take the case of a rolled beam, as before, to the flange of which is riveted a plate throughout its entire length; then the girder is what is usually described as one of uniform section, though, to be strictly accurate, it is not.

To find the strength, it is necessary to calculate the moment of inertia of the section of the compound girder through rivet holes, deducting the area of the holes in the tension side, but including the area on the compression side for obvious reasons.

To calculate the deflection, however, this moment of inertia is of no use, as the result of using it would be to calculate the deflection of a girder in which parallel slots had been planed along the lines of rivet holes instead of one in which a succession of holes had been drilled. We must, therefore, find the *mean* or average section and calculate the moment of inertia of this. Thus in Fig. 1 there are holes of 1 inch diameter through the flange plates, spaced at 4 inches apart (centre to centre). In one lineal foot of plate there are six rivet holes, which reduce the area of the plate from 144 square inches to 139.8 inches. The mean width is, therefore, 139.2 ÷ 12, or 11.6 inches.

The net width of the plate for estimating the stress is, however, 12 — 2 = 10 inches.

The moment of inertia for deflection should, therefore, be calculated on the basis of a width of plate of

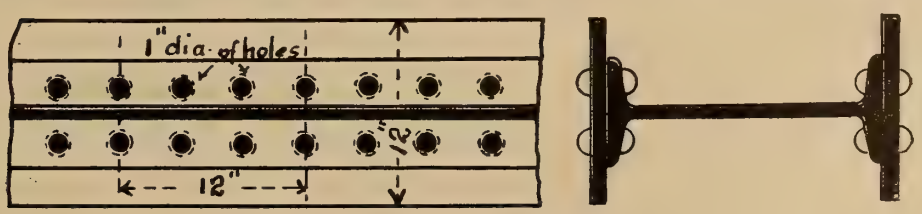


FIG. 1.—SECTION OF FLANGE GIRDER

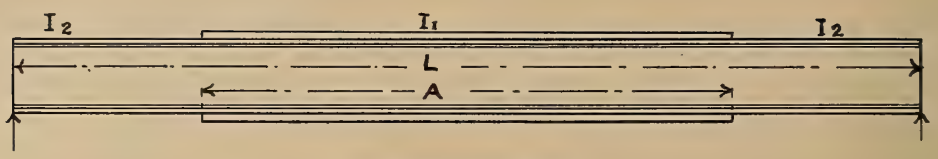


FIG. 2.—COMPOUND GIRDER

11.6 inches for the deflection formula and one of 10 inches for the stress formula.

Now if I_2 is the *mean* moment of inertia (for deflection), and I_1 is the *net* moment of inertia (for stress), with the same notation as before

$$\Delta = \frac{5}{384}\frac{WL^3}{EI_2} \text{ and } F = \frac{WLY_1}{8I_1}$$

$$F = \Delta \times \frac{48}{5}\frac{EY_2}{L^2} \times \frac{I_2}{I_1}$$

The effect of the rivet holes on the compression side of the neutral axis may be neglected with safety. It is more accurate, as a rule, to ignore them than to deduct their area, as in the tension flange, since only a small proportion of them should be defective, and in ordinarily good work the rivets will be able to transmit the compressive stresses. In calculating the *mean* moment of inertia, all the rivets in web joints and web stiffeners are ignored, since they occur but seldom, and make no appreciable difference to the average cross section of the girder.

Now in the case of a theoretically perfect girder, in which the moment of inertia and the modulus are everywhere proportional to the bending moment, the deflection $= \frac{WL^3}{64EI_2}$, where I_2 is the *mean* moment of inertia at the centre and the stress $= \frac{WLY}{8I_1} = \Delta \times \frac{8EY}{L^2} \times \frac{I_2}{I_1}$.

In no plate girder, however, can this proportion be exactly maintained, since there is a large excess of section at the ends intended to take up shearing stresses. This excess is principally in the web, which usually is not included in the calculations for bending moment, and the remainder of the excess, which is in the flanges, is due to the necessity of having some flange area throughout the girder.

Now let us take the case of the compound girder before mentioned, in which the flange plate does not extend the whole length of the girder, but is cut off, as shown in Fig. 2. Let the length of centre portion be A.

If the *net* moment of inertia of the centre (stronger) be I_1, and *mean* moment of inertia of the centre (stronger) portion be I_2, and the *mean* moment of inertia of the end (weaker) portion be I_3, then the deflection $= \frac{5}{384}\frac{WL^3}{EI_2} \times K$, where $K = 5 - \frac{(1-n)(12m - 6m^2 - 4m^3 + 3m^4)}{5n}$

and $n = \frac{I_2}{I_1}$, and $m = \frac{A}{L}$,

and stress as before $= \frac{WLY_2}{8I_1}$.

$\therefore$ Stress $=$ deflection $\times \frac{48}{5}\frac{EY_1}{L^2} \times \frac{I_2}{I_1} \times \frac{1}{K}$.

In this case, therefore, there are three moments of inertia to be calculated before the stress can be deduced from the deflection.

The most convenient way to use the correction is to plot graphically values for K for varying values for m and n, between the limits of $m = 0.5$ to $m =$ unity, and $n = 0.5$ to $n =$ unity. Calculate the deflection as

usual, and multiply by value of K as found on the graphic diagram.

In most plate girders designed for a uniformly distributed load the moment of inertia is of the form $I = KM + C$, where M is the bending moment and K and C constants (Fig. 3). This arises from the fact that the flanges are designed to be proportional to the bending moment, but the strength of the web is extra to this and approximately uniform. In such a case if I *max.* is the moment of inertia at the centre and I *min.* is the moment of inertia at the ends, then if $n = \frac{I \text{ min.}}{I \text{ max.}}$, the deflection =

$$\frac{WL^4}{64EI\max}\left\{1 - n\left(\frac{1}{6} + \frac{1-n}{15} + \frac{(1-n)^2}{28} + \text{etc.}\right)\right\}$$

In the case where $n = 1$ (i. e., the girder is of uniform section) the series

$$\frac{1}{6} + \frac{1-n}{15} + \frac{(1-n)^2}{28} + \text{etc.} = \frac{1}{6}$$

and the deflection

$$\frac{WL^4}{64\,EI}\left(1 - \frac{1}{6}\right) = \frac{5}{384}\,\frac{WL^4}{EI}$$

which has already been referred to as the formula for the deflection of girders of uniform section. In the case where $n = o$ (i. e., the girder has its moment of inertia proportional to bending moment) the deflection $= \frac{WL^4}{64\,EI}$, which has already been referred to as the formula for the deflection of such a girder.

If this formula is in constant use, it is well to plot graphically values for the expression

$$1 - n\left(\frac{1}{6} + \frac{1-n}{15} + \frac{(1-n)^2}{28} + \text{etc.}\right)$$

for values of N lying between ° and 1; the values of the expression will be found, as shown above, to be between 1 and 5/6.

It is unnecessary to consider more than three terms of the series, so that we have approximately:

Deflection =

$$\frac{WL^4}{64\,EI\text{ max.}}\left\{1 - n\left(\frac{1}{6} + \frac{1-n}{15} + \frac{(1-n)^2}{28}\right)\right\}$$

$$\frac{WL^4}{64\,EI\text{ max.}}\,(1 - .27n + .14n^2 - .035n^3)$$

And the stress = Deflection =

$$\times \frac{8\,Ey}{L^2} \times \frac{I_2}{I_1} \times \frac{1}{K}$$

Where $K = 1 - .27\,n + .14\,n^2 - .035\,n^3$.

I_1 = *net* moment of inertia at centre.

I_2 = *mean* moment of inertia at center.

n = ratio of *mean* moment of inertia at ends to that of centre.

All the formulæ up to the present have been those for uniformly distributed loads, whereas most railway girders have to be tested by means of a series of concentrated axle loads. It will be sufficiently accurate to assume the uniformly distributed load, which gives the same maximum bending moment as the concentrated loads, except for girders of small span.

If the deflection is due to a single concentrated load at the centre of the girder, the deflection $= \frac{WL^3}{48\,EI_2}$

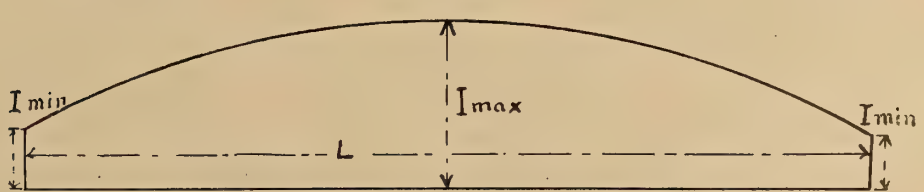


FIG. 3.—DIAGRAM FOR UNIFORMLY DISTRIBUTED LOAD

and the stress $= \frac{WLY_1}{4I_1}$, where I_1 is the *net* moment of inertia, and the stress $=$ deflection $\times \frac{12EY_1}{L^2} \frac{I_2}{I_1}$.

We see that, whereas for the same stress a concentrated load may be replaced by an equivalent uniformly-distributed load of double its amount, on the other hand the deflection will not be the same in both cases.

In the first case:

$$\text{Deflection} = \frac{WL^3}{48EI_2} = \frac{8}{384}\frac{WL^3}{EI_2}.$$

In the second case:

$$\text{Deflection} = \frac{5 \times 2WL^3}{384EI_2} = \frac{10WL^3}{384EI_2}.$$

In girders which are tested by axle loads of locomotives the error of obtaining an equivalent, uniformly-distributed load, and of substituting it in the deflection formula, may be neglected when more than two loads are placed simultaneously on the girder. In smaller spans it is better to test the girder with a single load at the centre.

Now in all these cases the stress is the only real quantity which is required in order to ascertain the amount of load any particular girder can bear, and it may not be quite apparent, perhaps, what is the use of the deflection tests and formulæ.

Up to the present no mention has been made of the ordinary calculations made in the design of girders, and especially of plate-girders.

Briefly, the assumptions made are as follows:

Instead of calculating the moment of inertia of the whole section of the girder, the flanges only are assumed to resist bending moment. If A is the net flange area, F the safe stress per square inch, D the depth of the girder measured between centres of gravity of flanges, then the moment of resistance of the girder will be $A\,F\,D$; and if M is the safe bending moment, $M = A\,F\,D$.

To calculate the bending moment M, the span is usually measured between centres of bearings, and not between the edges of bearings (or the clear span).

In the cases of girders of larger span, their ends are often supported on rockers, and the span can with accuracy be taken as the distance between the centres of bearing pins. When, however, as in the case of all girders of moderate span, the bearing is a flat one, it is quite possible that, owing to the lower surface of the girder and the surface of the abutment not being parallel, the bearing is either at the extreme end of the girder or else at the front edge of the bearing. In the former case the span should be taken as the over-all length of the girder, and in the latter as the clear span of the girder. Recent tests have shown that in nearly every case the latter state of affairs exists, viz.: that the clear span of the girder is the actual span when under load. This fact, of course, increases the factor of safety. For uniform load, W tons per foot run, the bending moment is $\frac{WL^2}{8}$, hence, if L has been taken for purposes of design as 50 feet, and it is actually 48, the bending moment is actually $\frac{48^2}{50^2}$ of what the girder has been designed for. To arrive, then, at the actual stress in the girder from deflection measurements, we equate the calculated deflection to the measured deflection and find for what span L they are equal. Then in the formula—

stress $= \frac{WL^2}{8Z}$, we substitute the values of L and Z to obtain the stress. The results are, naturally, considerably less than those obtained by the ordinary method of taking the mean span of the girder (centre of bearings), net area of tension flange and depth of girder over angles, and using these values in the formula-

stress $= \frac{WL^2}{8DA}$, where D = depth and A = flange area.

The latter method of design is, however, quite a sensible one for plate girders, as a rule, and it is all the better for erring on the safe side. When it comes to testing girders by deflection these rough-and-ready methods of calculation do not apply, and more accurate ones are necessary.

We will now consider some examples of actual deflection tests recently carried out. In the case of a series of bridges, consisting of plate and trough girders, of steel and wrought iron, of all spans from 10 feet to 130 feet, calculations on ordinary plate girder assumptions showed that some of the flanges were considerably overstressed by the loads in use.

It was decided to test the girders with axles of known weight to ascertain what stresses actually existed. These tests were carried out as carefully as possible, and the deflection readings at the centre of each girder were taken in such a way as to avoid errors caused by the movement of the girders on their bearings.

The method adopted was to stretch a wire along the girder as near the lower flange as possible, and to secure it to each end of the girder, tightening it by a screw shackle. The deflection of the lower flange at the centre was read on a scale to the nearest 40th of an inch. It would no doubt be better to take a more minute measurement of the deflection, but it was not found easy to do so in practice on a long series of tests.

When the readings were obtained, they were, in practically every case, considerably less than would have been expected had such stresses existed in the flanges as the previous calculations showed. From what has already been said about the method of calculation for plate girders, this does not seem an extraordinary occurrence. It was then found that, if the recorded deflections were to be reconciled with the calculated ones, fresh assumptions must be made as to span, moment of inertia, load, etc. The method of calculation was as has already been described. The only unknown was the span, and this must of necessity be of a value between the length of the clear span and the length of the girder over its end plates. That value which, when combined with the known weight per lineal foot of the testing engines, gave a deflection equal to the measured deflection, was taken to be the actual span. In nearly every case the result was nearest to the clear span of the girder. The stresses, recalculated on this basis, using the net moment of inertia of the section of the girder near the centre, were considerably less than those already calculated, and in many cases were so much less as to show the girder to be under-stressed instead of over-stressed, and to obviate the necessity of either renewal or strengthening.

There were a few cast-iron girders which were tested with the others. As the strength of such girders is always calculated on the true moment of inertia, and not on the flange area, the deflections agreed more closely with the calculations than in the case of the plate girders. As a rule, however, the assumed span was reduced to the clear span in the revised calculations.

The modulus of elasticity of the materials was taken at the following values, respectively:

Mild steel, 13,000 tons per square inch.

Wrought iron, 11,000 tons per square inch.

Cast iron, 5,400 tons per square inch.

There was no opportunity of checking these values in the different bridges tested; but the figures are average ones, and, generally speaking, are correct.

In all cases the loads used were stationary, or very slowly moving, so that the effects of impact were not

felt. To ascertain the effects of impact on the bridges, and to estimate what percentage should be added to the live load to cover them, would require a much more elaborate and extensive series of experiments than those referred to here.

From experiments made at different times no very definite information has been obtained, owing to the fact that the effects of impact depend largely on the condition of the permanent way, of the bridge itself, of the locomotive, on the proportion of dead to live load, as well as on the speed of motion.

Deflection tests are especially useful when it is required to find the proportion of load borne by various portions of a bridge consisting either of parallel connected trough girders, transverse or longitudinal, or of a series of ordinary cross girders spaced so closely together as to render it difficult to estimate the load borne by each.

In these cases the amount of load which each unit of the bridge has to bear depends upon the nature of the construction of the bridge—i. e., on the thickness of timber or ballast forming the intervening medium between the permanent way and the girders.

Practical experiments are necessary to demonstrate what these amounts and proportions are, and they naturally take the form of deflection tests.

In a particular case the bridge consisted of a series of wrought-iron trough girders, the centres of which were spaced three feet apart, and the lines of railway above, forming a rather complicated junction, were laid at all angles, intersecting over the bridge. The permanent way was carried on timber decking laid on the troughs, and it was not possible to estimate the exact amount of load carried by a single trough girder, as it was not known how much was the distributing power of the timber. Some of the rails were parallel to the troughs and immediately above them, and it was assumed that where this occurred the troughs would be most severely loaded, and one trough would bear the whole of the live load coming upon one rail—i. e., half the weight of the locomotive in use.

Actual tests, however, showed that this was not the case. By measuring simultaneously the deflection of eleven adjacent troughs, all of which were more or less affected by the test engines, the total load accounted for by these deflections, based on the moment of inertia of each trough and the clear span, closely approximated to the known weight of the test engines, but was slightly less.

The proportion borne by each girder was therefore known, and from this the stress in the girder could be calculated. The amount was found to be, not half that of a single locomotive, but about two-sevenths. The stress was, therefore, ascertained to be about one-half of that assumed from the calculations based on the mean span of the girders and the greater load.

No rule of general application can be deduced from these tests, since the capability of the superstructure to distribute the test load over the girders differs in various cases; but the conditions of each case can be ascertained by the practical method to check purely theoretical calculations.

Cross Girders.—Cross girders, as a rule, differ from main girders in that instead of being supported freely at their ends they are more or less rigidly held by their attachments to the main girders.

The amount of end fixation and the proportion of the bending moment at the end to the bending moment at the centre depend on the rigidity of the main girder, on its capability of resisting the torsional stresses produced by the cross girder, on the efficiency of the attachment of the cross girders, and, of course, on the depth and rigidity of the cross girder itself. In calculations for the design of cross girders the end fixa-

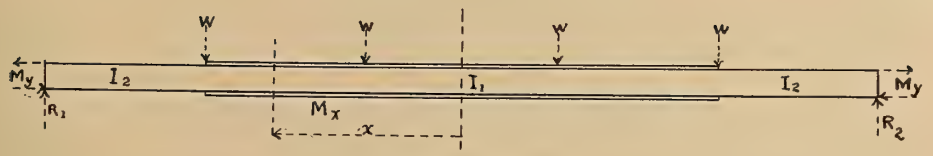


FIG. 4.—CROSS GIRDER

tion is usually neglected, owing to its being an unknown quantity, and the cross girders are designed as freely supported beams. To take a particular series of instances, the cross girders in a number of bridges, each carrying a double line of railway, appeared to be severely overstressed when the stresses were calculated on the usual assumptions.

Deflection tests were carried out, and the readings were much smaller than would have been found had any such stresses existed.

There was no doubt that a considerable amount of end fixation existed, and this was deduced from the deflection readings obtained in the following manner:

In Fig. 4 the end bending moment is unknown; but the four concentrated wheel loads, the span of the girder, the spacing of the loads, the moment of inertia of the girder at each point, and, approximately, the modulus of elasticity, are known.

By integrating the equation $EI \frac{d^2x}{dy^2} = Mx$ (the bending moment at any point), we get that the total deflection $y = pW + q\ My$, where p and q are some constants and My is the end bending moment.

From this equation we obtain a value for My, the end bending moment, by means of which we can get the maximum central bending moment, which equals the maximum bending moment of the girder freely supported at its ends, less My.

Since this end bending moment depends on the rigidity of the main girders and of the attachment of the cross girders to them, it will vary slightly in different cross girders in the same bridge, and its variation will be shown by the differing deflection readings obtained.

It must be assumed that the amount of fixation at each end of the cross girders is the same, or the problem of finding the bending moment is insoluble.

It will be seen how important it is to have rigid main girders and substantial connections between the cross girders and the main girders. Weakness in these respects causes increase of stress not only in the cross girders, but also in the main girders themselves. The end bending moment on the cross girders is equally effective on the main girders; but here it has the effect of increasing the stress in them, and they should be sufficiently strong laterally to withstand it. The wet stiffeners should be designed to take up this moment. Unless cross girders are suspended to the main girders by special connections designed so as to prevent any rigidity of attachment, this end bending moment must exist to a certain extent; and whatever the assumptions on which the cross girders are designed, whether they are considered to be free or fixed girders, the effect of the end bending moment will be felt by the main girders.

One difficulty in calculating the stresses in cross girders is to find the exact load coming upon each.

The testing should not be confined to one cross girder at a time, but at least three consecutive cross girders should be simultaneously and equally loaded with the desired test load. Preferably more than three should be loaded. The deflection reading should be measured on the centre cross girder, and to test other cross girders the system of loads should be moved forward.

The distributing power of the permanent way and longitudinal members of the floor of the bridge will affect the lead on the tested cross girder, unless some such method of testing is adopted.

The stresses calculated on the assumption of assistance from end fixation will, however, be greater than those calculated on any other admissible assumptions, and can be seen from the following:

Case 1.—Assume free ends and uniform load—

$$\text{Stress} = \frac{48}{5} \times \frac{Ey}{L^2} \times \text{deflection.}$$

Case 2.—Assume rigid horizontal fixation of ends and uniform load—

$$\text{Stress} = 16 \times \frac{Ey}{L^2} \times \text{deflection.}$$

Case 3.—Assume partial fixation at ends and uniform load—

$$\text{Stress} = \frac{Ey}{L^2} \times \text{deflection} \times \text{some value between } \frac{48}{5} \text{ and } 16.$$

Case 1 also assumes no stress at the end of the cross girder, whereas cases 2 and 3 show a reversal of stress at the ends, and the point of zero stress occurs at some intermediate point on the cross girder.

THE DEVELOPMENT AND DESIGN OF THE ELECTRIC LOCOMOTIVE

By Theodore Rich

THE design and construction of heavy electric locomotives have undergone remarkable development during the last few years; this has been largely due to the extended use of high-tension transmission, which enables power to be generated at economical central stations and distributed over long lengths of railway, with only a small loss on the way. Very soon after the practical demonstration of electric traction at the Berlin Exhibition in 1879, engineers and scientists began to realize that electric traction was likely in time to prove a serious rival to the steam locomotive. The difficulties confronted by the early experimenters were enormous, the power available was very small, and great obstacles were met with in the construction, insulation, suspension and gearing of the motors, to stand the wear and tear of railway working. It is somewhat remarkable that many of the so-called modern arrangements of motors and gearing were worked out by the early experimenters in the eighties.

The first traction motors were built to run at a high speed, and double gearing, ropes, belts or chains had to be used to reduce the speed down to that of the locomotive or car axle. In 1883 M. Raffard, the inventor of the well-known elastic coupling, patented in France the design of a locomotive with the motor field mounted on the main frame and the armature built up on a hollow shaft, connected to the driving wheels by means of rubber bands. The main axle passed through the hollow armature shaft with sufficient play to allow the springs to act and take the dead shocks of the heavy weight off the motor and roadbed. The motor proposed was of the multipolar type. This system was first used in practice some ten years later by the late Professor Short. In the year 1888 electric traction began to compete with horses and cables for street tramway work, and about the same time Frank Sprague and Leo Daft developed the single-geared motor, and an experimental locomotive was run on the New York Elevated Railway. In the same year Stephen D. Field built a locomotive, with a gearless motor driving the wheels of a bogie through two cranks, and later, in association with Mr. Eickemeyer, a number of tramway cars were driven on this principle (Fig. 1). The use of this construction was abandoned for some years; but, with the single-axle drive (Fig. 2), has recently been revived by a number of makers for heavy locomotive work. The three types of transmission, the gearless, the single geared, and the crank and connecting-rod, are those in use at the present day. Up to about twelve years ago the attention of electrical engineers was mainly directed towards tramways and underground railways, and locomotive design was somewhat neglected; but the advances in high-tension transmission and motor construction have led to remarkable developments in the direction of main line traction.

The general question of the electrical equipment of locomotives will only be dealt with briefly, and the merits of the different electrical systems discussed only with regard to their influence on design. There are

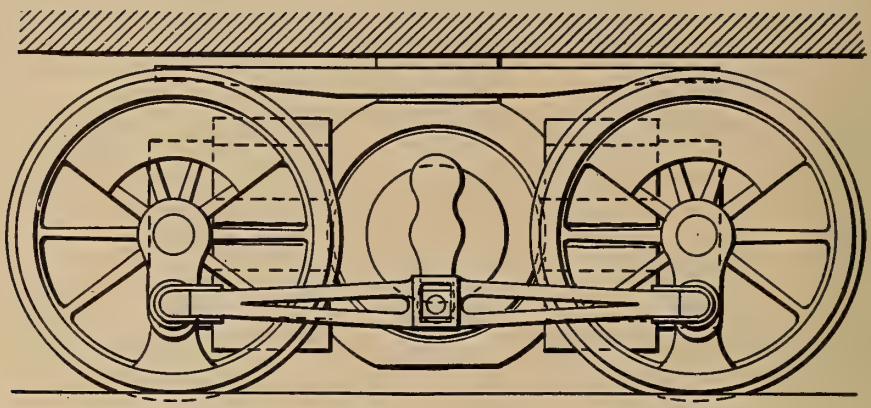


FIG. 1.—CRANK-DRIVEN BOGIE, FIELDS LOCOMOTIVE, 1888

three main electrical systems in use at the present day, the direct-current, the three-phase and the single-phase system. The direct-current system was the first to be developed, and the bulk of the heavy traction in Europe and America has been exercised with this system, though at this moment single-phase traction is making great strides. The usual direct-current pressure is 600 volts, though there are a few installations at 750 volts, the current being in most cases collected from a third rail with shoes. In some instances overhead conductors are used especially in conjunction with the third rail, to avoid danger to railway employees in large stations and goods yards. The high-tension, direct-current system, with current at 2,000 volts, is being developed in America and on the Continent, but the British Board of Trade regulations with regard to the permissible voltage drop in return rails are likely to hinder its adoption in Great Britain.

The three-phase system was first used by Brown, Boveri & Company between Bergdorf and Thun, in Switzerland, in 1899, with a pressure of 750 volts, and in 1902 the first high-tension railway was started at Valtellina, in Northern Italy, on the Ganz three-phase system, with 3,300 volts on the overhead wires and motors. A somewhat similar system has been recently used for hauling heavy trains through the Simplon Tunnel and the Cascade Tunnel, on the Great Northern Railway, in America. The three-phase motor allows of a very sound mechanical construction from a railway point of view, no commutators being required, and though there are only a few three-phase railways, the system can be very valuable where heavy, steady haulage has to be done.

The single-phase system has made rapid progress, due largely to the enterprise of the Westinghouse Electric & Manufacturing Company, in Pittsburg, Pa., U. S. A., and the Allgemeine Companie and Messrs. Siemens and Halske, in Europe. The single-phase system has the advantage that ten or fifteen thousand volts can be used on the overhead conductor, and no sub-stations with rotating machinery are required with an extensive system, as in the case of direct-current operation. However, the single-phase motor has the disadvantage that, from the nature of the machine, given exactly similar

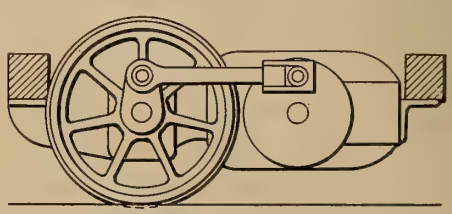


FIG. 2.—MOTOR AND CRANK-DRIVEN AXLE

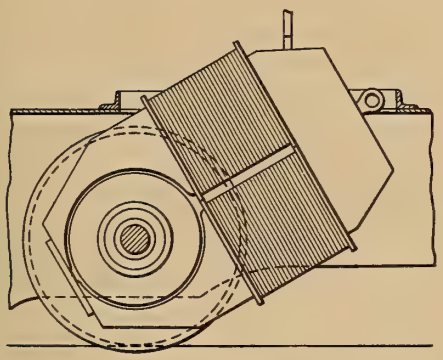


FIG. 3.—MOTOR EMPLOYED ON THE CITY AND SOUTH LONDON RAILWAY, 1890

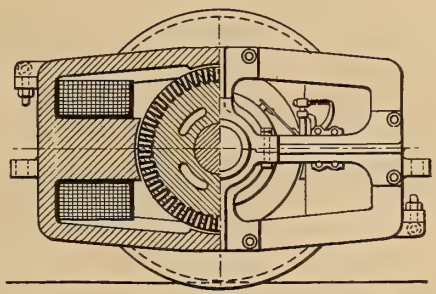


FIG. 4.—MOTOR USED ON CITY AND SOUTH LONDON RAILWAY

conditions of horse-power, speed of revolution, ventilation and allowable temperature rise, the weight and space taken up is greater than that of a motor of the direct-current or three-phase types.

On a locomotive extra weight is sometimes desirable, for adhesion purposes, up to the limit of axle load; but the question of space is very important. Where motors are placed directly on the axles or fitted with reduction gearing and hung low down between the frames, the space between the wheel flanges and below the axle level is very limited, and where one motor is attached to each driving axle the lower limit of output has considerable influence on design. Single-phase motors are of very similar construction to those of the direct-current type, and where suitable winding voltages, connections and switch gear are provided, single-phase locomotives can be worked over direct-current sections, suitable shoes or trollies being provided to deal with the low-pressure current.

On taking up the design of a locomotive, the horse-power drawbar pull and speeds are settled on from the nature of the traffic, the gradients, curves, etc., the electric system and the permissible axle load being usually fixed beforehand. One of the first steps is to settle the type of gearing or transmission, then the number of driving axles and motors, and later the general electrical and mechanical arrangements.

Considering the question of gearless and geared motors, at first sight the motor with the armature mounted direct on the axle would seem to be the ideal arrangement; it seems simple, and there is no loss of power

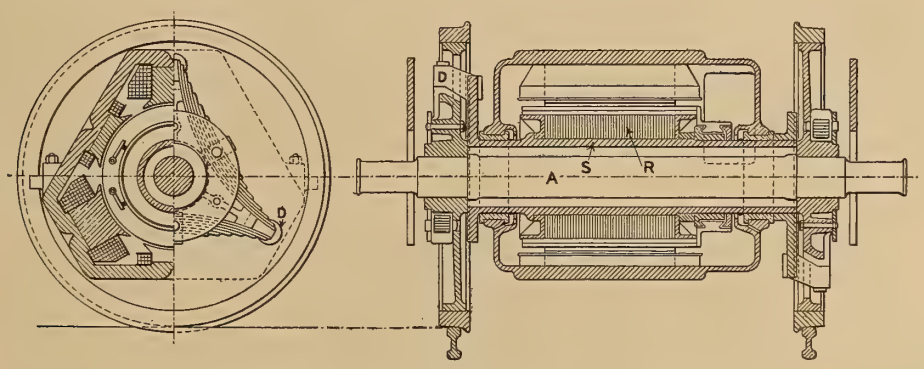


FIG. 5.—SECTION OF TYPICAL SPRING-SUPPORTED GEARLESS MOTOR

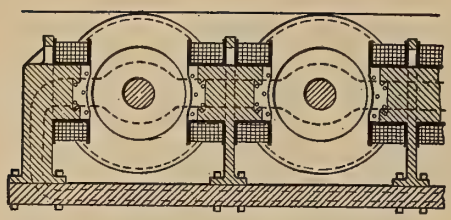


FIG. 6.—MAGNETIC CIRCUIT, NEW YORK CENTRAL LOCOMOTIVES

through gear wheels, the absence of the latter tending toward quiet running. Yet gearless motors have some grave disadvantages. In the first case it is always desirable to reduce the unsprung weight on the axle to a minimum, any heavy weights, like an armature and field, tending to pound the rails and produce vibration in the neighbourhood, the latter difficulty leading to the abandonment of solid gearless motors on the Central London Railway some years since.

In order to build a motor of the maximum efficiency with the minimum weight of copper and iron, it is necessary to run the armature with a high peripheral speed. With the gearless motor, in order to allow radial depth for the field or stator windings, and also for the clearance above rail level, the peripheral speed can only be about 60 per cent. of that of the driving wheel; and, therefore, to get high efficiency with reasonable first cost, the average running speed of a gearless locomotive should be high, any increase in power above a certain limit meaning a larger motor diameter, a larger wheel diameter and a lower speed revolution.

Geared motors can be run with a high armature speed, with small driving wheels, at a comparatively low running speed, and they are lighter, more easy to handle and cheaper to build than gearless axle motors, and are very suitable for locomotives of medium power with a large economical range of speed. The crank-driven locomotive, which combines some of the advantages of the geared and gearless types, will be dealt with later.

The first locomotives used commercially for train haulage were those designed by Dr. Edward Hopkinson and built by Messrs. Mather & Platt, of Manchester, for the City & South London Railway, and set to work in 1890. Two bipolar motors were fitted, with the armatures built up solid on the axles, the main weight of the field magnets being also supported direct by the axles (Fig. 3). The motors were of 50 horse-power each, the locomotive weighing 13 tons, hauling a three-car train of 21 tons at an average speed of 16 miles an hour. Further motors of the same type were built by Messrs. Siemens Brothers & Co., and some ten years later some more powerful

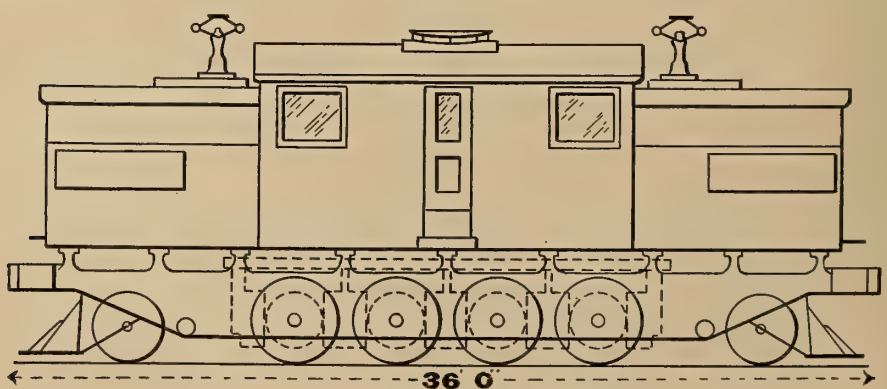


FIG. 7.—NEW YORK CENTRAL LOCOMOTIVE

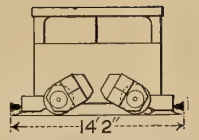


FIG. 8.—CITY AND SOUTH LONDON RAILWAY, 1890. MATHER & PLATT

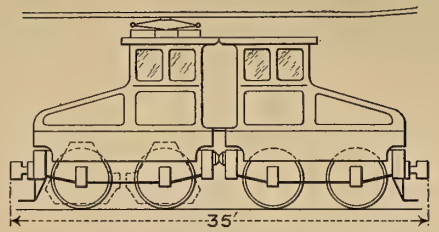


FIG. 9.—BALTIMORE TUNNEL LOCOMOTIVE, 1895

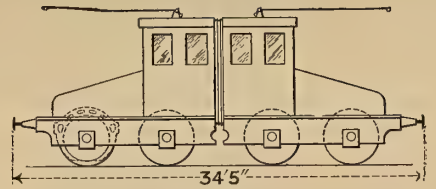


FIG. 10.—THREE-PHASE GOODS LOCOMOTIVE. GANZ & CO.

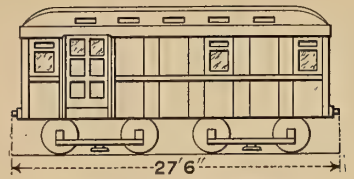


FIG. 11.—B. T. H. LOCOMOTIVE, MET. DIST. RY.

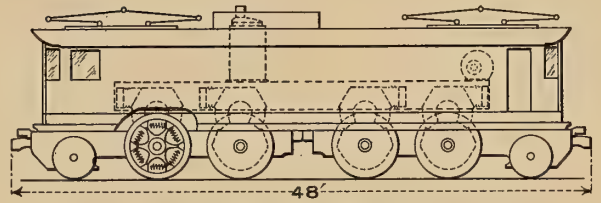


FIG. 12.—NEW YORK, NEW HAVEN AND HARTFORD RAILWAY WESTINGHOUSE LOCOMOTIVE

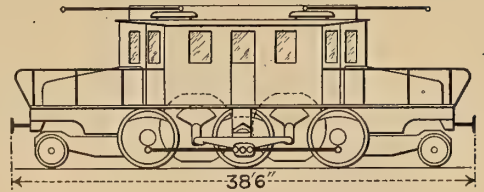


FIG. 13.—VALTELLINA RAILWAY, 1904. GANZ & CO., BUDAPEST

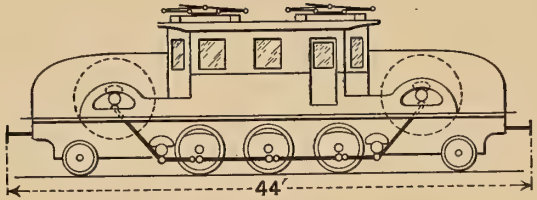


FIG. 14.—WIESENTAL, BADEN STATE, 1910

locomotives for hauling five-car trains were built by Crompton & Co. Fig. 4 shows the type of motor used. Gearless motors of this same general type were used for the original equipment of the Central London Railway.

When locomotives of greater power were required it was found that the unsprung weight of motors of the solid axle type was too great for the roadbed, and the Raffard type to the driving wheels by springs, rubber pads or drag links at *D D* leaf springs being shown in this case. The field (or stator) is bolted on to the main frame or truck, the motor bearings being at *B B*. The axle passes through the hollow sleeve and has a limited play. The field of the motor shown is of the six-pole type. In 1895 96-ton locomotives with four 360 horse-power motors of the Raffard-Short type were built by the

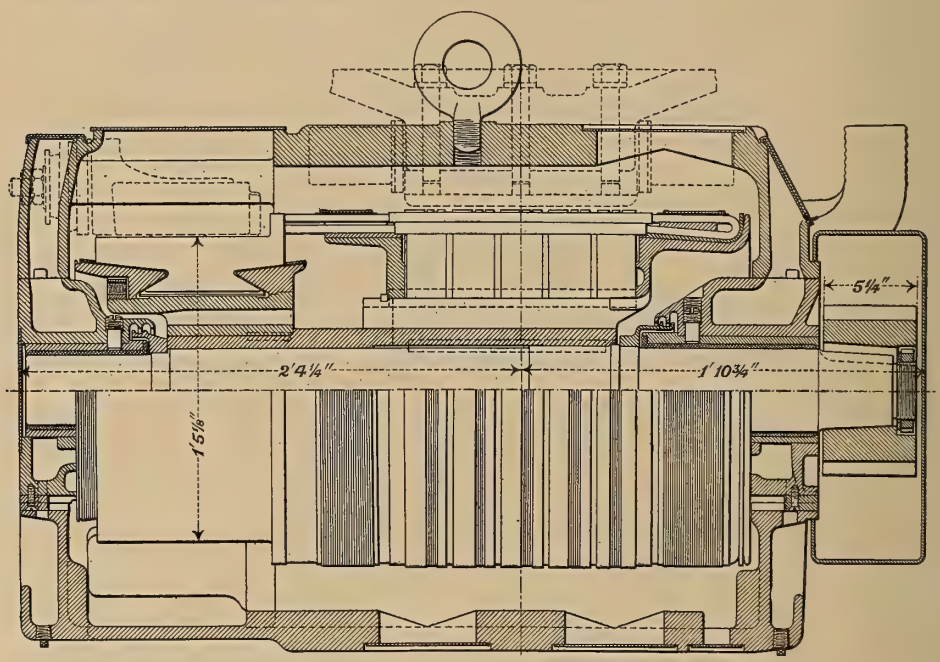


FIG. 15.—SECTION OF HEAVY WESTINGHOUSE TRACTION MOTOR, LONDON METROPOLITAN RAILWAY

of hollow-shaft motor was developed in America by Professor Short; a 30-ton locomotive of this type was built in 1894 and exhibited at the Chicago Exhibition, since that time a large number of locomotives having been built on this principle on both sides of the Atlantic.

A diagram of a motor of this type is shown in Fig. 5. The motor is of the direct-current type, though the same general mechanical arrangements are used for those of the single-phase or polyphase types. The armature, or rotor *R*, is mounted on a hollow sleeve or quill *S*, attached

General Electric Company and the American Locomotive Works for hauling heavy trains through the Baltimore tunnel, where difficulty was to be met with from smoke. These locomotives were built on two four-wheeled trucks, in two halves, with an overlapping floor and roof. This was the first example of electric traction with heavy main-line trains. Fig. 9 shows the locomotive. Goods locomotives of a somewhat similar design with four 250 horse-power, three-phase motors, were set to work in Italy by Ganz & Co. some six years later (Fig. 10). Direct-current gear-

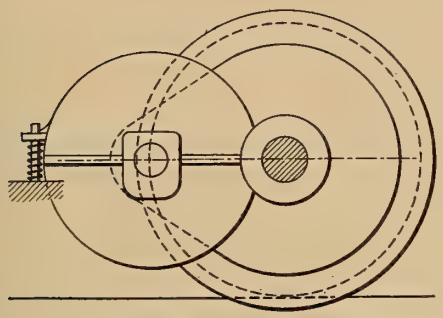


FIG. 16.—GEARED MOTOR SUSPENSION

less locomotives with the same type of motors were built by the Société Alsacienne for the Paris-Orleans Railway type shown in Fig. 5, and in recent years a number of single-phase locomotives have been built by the American Westinghouse Electric & Manufacturing Company for the New York, New Haven & Hartford Railway, with somewhat similar hollow-shaft motors.

A modified form of gearless motor is used on the direct-current locomotives of the New York Central Railroad (Figs. 6 and 7). The motors are of the bipolar type, the magnetic field of the four motors being in series, with a return through the heavy yoke piece *Y*, the field system being supported on springs. The air-gaps are made very large and the pole tips cut away, so that the armatures, which are built up solid on the axles, can have an up-and-down play on the springs. Owing to the large stray field from the bipolar magnets, heavy guards have to be placed under the motors to prevent spikes or other pieces of iron from being picked up. In the latest locomotives of this type a bogie truck is used at each end instead of a pony truck, to reduce the pitching of the locomotive.

A large number of locomotives of medium power have been fitted with geared motors, the gear being of the single-reduction type. The gear is placed in a malleable iron or steel gear box, the general arrangement being similar to that in use on tramways, but on a larger scale, the motor being supported on the axle on one side and on springs on the other.

The advantages of geared motors are that they are light in weight for their power, easy to handle and cheap to make, as the armature can be run at a high speed in proportion to the speed of the driving wheels. The driving wheels can be of small diameter, which allows of a medium gear ratio, these factors allowing an economical design to be used for low and medium locomotive speeds. In most cases only one set of gear is used; but for the highest powers it has been found advisable to have two sets, one on each side of the motor, to reduce twisting strains on the motor and lead to even wear on the wheel teeth. Gear ratios up to 1 to 5 can be used; but it is advisable to use lower ratios for high powers, as too high a gear tends to excessive wear. At the highest speeds the revolutions of the armature are limited by the limiting speed of the commutator under the brushes and that of the armature core. The diameter of the driving wheels must be large enough to give sufficient clearance under the motor shell.

One of the difficulties of constructing powerful geared locomotives without too many driving axles is to get motors of sufficient power into the confined space between the wheel flanges, and considerable ingenuity

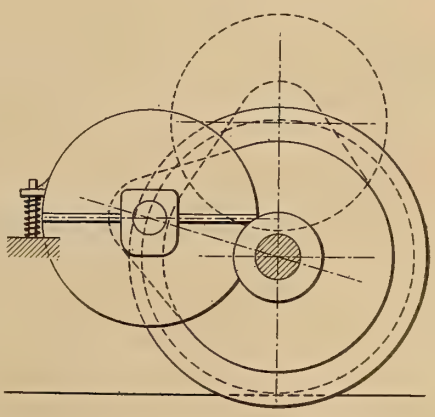


FIG. 17.—GEARED MOTOR RAISED

Table of Electric Locomotives.

Gearless Type.

Date Working.	Type.	Current.	Voltage.	Railway.	Maker of Electric Equipment.	Overall Length.	Diam. of Drivers.	Number and H. P. Each Motor.	Weight in Tons.	Fig. No.
1890	4.2M	Direct.....	500	City and South London.....	Mather & Platt.....	14′ 2″	27″	2 of 50 H. P.	13	8
1895	8.4M	Direct.....	600	Baltimore Tunnel.....	American General Electric Co...	35′ 0″	62″	4 of 360 H. P.	96	9
1901	8.4M	Three phase...	3,000	Valtellina, Italy.....	Ganz & Co.....	33′ 0″	54⅜″	4 of 225 H. P.	46	10
1905	8.4M	Single phase....	11,000*	New York, New Haven & Hartford	American Westinghouse Co.....	36′ 4″	62″	4 of 250 H. P.	77	23
....	2, 8.4M, 2	Direct.....	600	New York Central.....	American General Electric Co...	.. ..	47¼″	4 of 550 H. P.	7	7

Geared Type.

1905	8.4GM	Direct.....	600	London Metropolitan.....	British Westinghouse.....	35′ 9″	36″	4 of 250 H. P.	50	18
1907	8.4GM	Direct.....	600	London Metropolitan.....	British Thomson-Houston.....	33′ 6″	38″	4 of 240 H. P.	47	..
1905	8.4GM	Direct.....	600	London, Metropolitan District....	British Thomson-Houston.....	27′ 0″	36″	4 of 200 H. P.	38	11
1909	8.4GM	Direct.....	600	British Columbia Electric Railway.	Dick, Kerr & Co.....	35′ 7″	42″	4 of 160 H. P.	50	20
1906	8.4GM	Direct.....	2,000	Mazieres Minerals.....	Siemens-Schuckert.....	34′ 2″	49″	4 of 160 H. P.	55	19
1908	8.4GM	Three-phase....	6,000	Great Northern, U. S. A.....	American General Electric Co...	44′ 2″	60″	4 of 400 H. P.	102	..
1908	8.3GM	Single phase....	6,000	Prussian State.....	Allgemeine Co..(A. E. G.)	46′ 5″	55″	3 of 350 H. P.	59	21
1907	12.6GM	Single phase....	15,000	Seebach-Wettingen.....	Siemens-Schuckert.....	45′ 11″	..	6 of 225 H. P.	79	22
1909	2, 8.4GM, 2	Single phase....	11,000	New York, New Haven & Hartford	American Westinghouse.....	48′ 0″	63″	4 of 350 H. P.	116	12

Crank and Gear Drive.

1899	4+2GM	Three phase....	750	Bergdorf-Thun.....	Brown, Boveri & Co.....	27′ 5″	48″	2 of 150 H. P.	29	24
1904	4+GM, 4+GM	Single phase....	15,000	Seebach-Wettingen.....	Oerlikon Co.....	41′ 5″	41″	2 fo 200 H. P.	42	25
1910	6+GM, 6+GM	Single phase....	6,600	St. Polten-Mariazell.....	Siemens-Schuckert.....	36′ 9″	32″	2 of 250 H. P.	48	26

Crank and Gearless Drive.

1904	2, 6+2M, 2	Three phase....	3,000	Valtellina, Italy.....	Ganz & Co.....	37′ 10″	59″	2 of 600 H. P.	62	10
1907	2, 6+2M, 2	Three phase....	3,000	Simplon Tunnel.....	Brown, Boveri & Co.....	40′ 4″	65″	2 of 550 H. P.	62	27
1909	4+2M+4	Three phase....	3,000	Simplon Tunnel.....	Brown, Boveri & Co.....	38′ 2″	49″	2 of 850 H. P.	68	28
1910	10+2M	Three phase....	3,000	Genoa Italian State.....	Italian Westinghouse.....	31′ 2″	42″	2 of 1000 H. P.	60	29
1909	4, M+6, +M 2	Single phase....	.....*	Experimental.....	American General Electric Co...	47′ 6″	49″	2 of 800 H. P.	..	31
1910	2, M+6+M, 2	Single phase....	10,000	Wiesenthal Baden State.....	Siemens-Schuckert.....	43′ 2″	47″	2 of 500 H. P.	62	14
1909	4, M+4, 4+M, 4	Direct.....	600	Pennsylvania.....	American Westinghouse.....	64′ 11″	68″	2 of 2000 H. P.	149	32

* Also arranged for direct current, 600 volts. + Metric original dimensions to nearest inch.

has to be used to cut down the width of the motor, as the pinion and gear box take up about all of that available.

This is especially the case with motors of the single-phase type, which require long commutators, or with narrow gauge locomotives. Fig. 15 shows a section of a heavy traction motor of the Westinghouse type used on the London Metropolitan Railway. The illustration, though not that of the latest Westinghouse type in use on this railway, shows the compactness of the design and the way in which the length of the shaft is saved by arranging the bearings and spindle underneath, part of the commutator on the one side and part of the armature spider and windings on the other.

At one time the spindles of geared motors were kept level with the axles as shown in Fig. 16, but in order to give greater clearance or allow of a greater diameter of shell the motors are frequently canted up, as shown in Fig. 17. This can be done without difficulty, as there is no fixed floor level to interfere with.

Practically all the locomotives built in England have been of the geared type. Fig. 18 shows a 50-ton Westinghouse locomotive fitted with four 250 horse-power motors on bogie trucks supplied to the London Metropolitan Railway, the switch gear being of the Westinghouse Electro-pneumatic type. Another type of geared locomotive, with the cab extending the full length, fitted with B. T. H. (British Thomson Houston Company's) equipment, has been supplied to the same railway. Both types are used for hauling trains from Harrow and Bishops Road through the underground section. Somewhat similar locomotives are used on the London District Railway for hauling 80-ton trains round the Inner Circle; these are of the single-ended type, and were originally used in pairs for hauling London & North Western trains from Earls Court to the Mansion House (Fig. 11). The framework for the above locomotives was built by the Metropolitan Railway Carriage Company. Further details of the above and following will be found in the

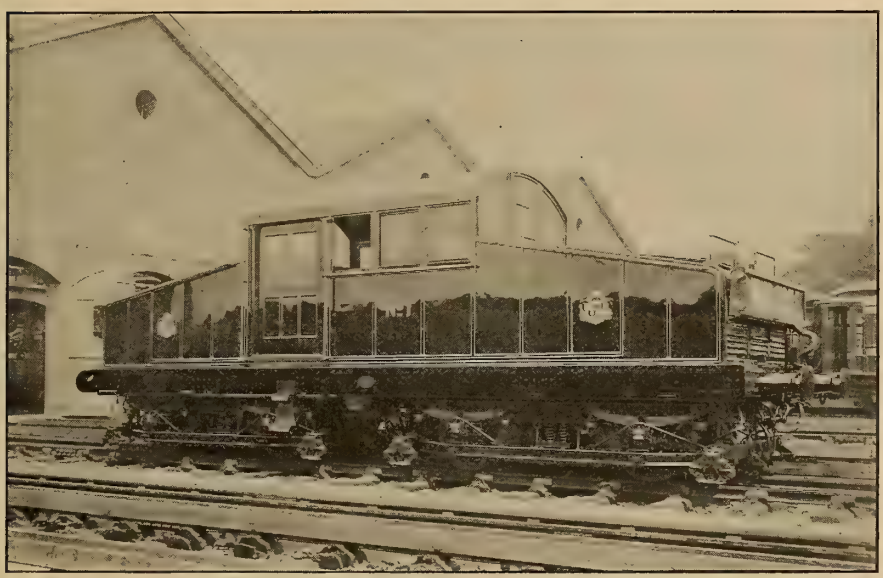


FIG. 18.—WESTINGHOUSE LOCOMOTIVE, LONDON METROPOLITAN RAILWAY

FIG. 19.—SIEMENS-SCHUCKERT HIGH-TENSION, DIRECT-CURRENT GOODS LOCOMOTIVE

tables. An interesting type of locomotive built by the Siemens-Schuckert Werke, Berlin, is for hauling 300-ton mineral trains over a metre gauge line (Fig. 19) in the mining district of Lorraine. The direct-current pressure used is 2,000 volts, and the motors are of very compact design, to give 160 horse-power each on a narrow gauge.

A type of locomotive built in 1908 by Dick, Kerr & Co., of Preston Lancs, for heavy haulage on the British Columbia Electric Railway, is shown in Fig. 20. Four geared motors are fitted; these are actuated by means of the Dick-Kerr system of solenoid control. The motors are not mounted on bogies, but on two trucks with a massive central hinge, designed to resist any tendency to tilt, while giving horizontal flexibility. The cab rides on the two trucks, but takes no strain from the draw bars. This system of truck construction has advantages for heavy work, and a somewhat similar construction has been used recently in America.

Heavy three-phase locomotives of the American General Electric type are used for hauling goods and passenger trains through the Cascade Tunnel on the Great Northern Railway, U. S. A. Transformers are used to reduce the line pressure, and though this means a certain loss of efficiency, this loss is largely compensated for by the high pressure on the line — 6,000 volts — the extra weight being useful for adhesion; in this case double gears are used for the motors, which are of 450 horse-power.

Fig. 21 shows a high-tension, single-phase locomotive built for goods service on the Oranienburg Belt Line of the Prussian State Railway by the Allgemeine Companie, of Berlin. Three 350 horse-power motors are fitted, provision being made for a

fourth. Two separate four-wheeled trucks are used, each half of the cab being built on the truck frames. A Siemens-Schuckert locomotive (Fig. 22) has been used on the experimental single-phase section of the Swiss Federal Railway from Seebach to Wettingen, near Zurich; the line pressure is 15,000 volts, and a 225 horse-power geared motor is fixed on each of the axles.

In America, in order to use high-powered, single-phase geared motors without the usual limitations of space, it has been found practicable to place the motor on the top of the driving axle inside the locomotive cab, as dotted in Fig. 17, and not inside the frames. In order to take the dead weight off the axle, the motor is mounted on the truck frame, and drives by means of two pinions, one at each end, two gear wheels mounted on a hollow shaft or quill. The driving axle is placed inside this shaft, with ample play for the springs, and the wheels are driven by means of flexible connections (in this case spiral springs) to arms placed at the ends of the hollow shaft on the gear wheels. The principle is similar to that of the Raffard gearless motor illustrated in Fig. 5, a countershaft replacing the motor armature. This construction is used by the American Westinghouse Company for one of the latest locomotives on the New York, New Haven & Hartford Railway (Fig. 12).

Owing to the limited space available, after deducting that required for the gear, it has not been found practicable to build geared motors much over 400 horse-power, the limit with single-phase motors being usually somewhat lower, difficulties in lubrication being also found with high-speed gearing; and, therefore, when very high power is required, it is either necessary to have a number of motors, or two or three locomotives must be coupled together and con-

FIG. 20.—DICK-KERR LOCOMOTIVE, BRITISH COLUMBIA RAILWAY

FIG. 21.—ALLGEMEINE ELEKTRIZITAETS-GESELLSCHAFT GOODS LOCOMOTIVE, ORANIENBURG LINE, PRUSSIAN STATE RAILWAYS

FIG. 22.—SIEMENS-SCHUCKERT SINGLE-PHASE LOCOMOTIVE, SWISS FEDERAL RAILWAYS

trolled by the multiple-unit system when heavy loads have to be drawn (Fig. 23).

The limitations of output of motors of the gearless and normal geared type has led to the development, in the last ten years, of a class of locomotives built somewhat on the same lines as those driven by steam. The motor, or a motor with reduction gear, is mounted solid onto the frame or truck, and is attached to the driving wheels by means of cranks, connecting-rods and coupling-rods. This class of locomotive has some considerable advantages for dealing with heavy main-line passenger and goods traffic. The motor can be of large diameter and placed between the axles or where it is most convenient, the armature or rotor can be of larger diameter than the driving wheels, and by means of small drivers a high speed of revolution can be secured with a large starting torque, due to the large armature diameter. Due to the high peripheral speed, the motor can be of economical design, and there is ample width available, as the cranks are placed on the outer sides of the driving wheels.

In steam locomotive practice it has been found advisable to keep the centre of gravity high, as this tends to steady running and reduces the pounding effect on the rails. One objection to the older type of electric locomotives has been the very low centre of gravity, which has a serious effect on the roadbed; in one instance the surging and bursting effect of a very low centre of gravity is said to have led to a serious accident when running at a high speed round a curve.

FIG. 23.—WESTINGHOUSE SINGLE-PHASE LOCOMOTIVES, NEW YORK, NEW HAVEN AND HARTFORD R. R.

The motors of crank-type locomotives can be lifted up above the frames, and the centre of gravity can be made as high as that of the steam locomotive. There are no advantages in multiplying the number of motors other than that of the larger reserve in case of breakdown and the convenience of handling small weights. One or two large motors are cheaper to make than a number of small ones,

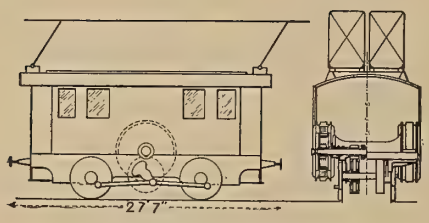


FIG. 24.—BROWN-BOVERI THREE-PHASE GOODS LOCOMOTIVE

and the cost of repair and up-keep is less; and as with the crank-type locomotive the motor is usually well out of the dust and freer from shock than other types, there is not so much individual liability to breakdown. With this construction the limit of output of each motor does not so much depend on the space available as on the number of driving axles that can be crank-driven with a fixed wheelbase from one motor or two motors coupled, the ultimate pull from each pair of driving wheels being limited by the allowable axle loading. In America, where very heavy axle loading is allowed, one 2,000 horse-power motor is used in some of the latest designs to drive two axles.

As previously stated, this type of locomotive was first experimented on by Stephen Field; but the first commercially used was built by Brown, Boveri & Co., of Baden, Switzerland, to work goods traffic over the three-phase railway from Bergdorf to Thun, opened in 1899. This type was arranged with two large-diameter motors on a common shaft, geared by means of two-speed change wheels to a dummy crankshaft, four connecting-rods being used to drive the four wheels of the locomotive (Fig. 24). It will be noted that in order to raise the motor and gear and give ample clearance above the rail level, the crank-pins of the dummy shaft are somewhat higher than those of the driving wheels. The use of horizontal connecting-rods allows play to the driving axles. To use a modified railway notation, this locomotive might be termed one of the 2 + 2 G M + 2 type. Somewhat similar arrangements were used by the Oerlikon Company of Zurich on a locomotive built for the Seebach-Wettingen experimental section in 1904 (Fig. 25). Two open-type motors fixed on swiveling trucks are placed inside the cab, where they are easily accessible. Each motor is geared to a dummy crankshaft with connecting-rods to two pairs of wheels. Play is given to the dummy crank-pin brasses to allow the springs to act. As in all cases of high-tension single-phase traction, a transformer is carried, to reduce the voltage from the overhead conductor and regulate the voltage, and, therefore, the speed of the motors. This locomotive might

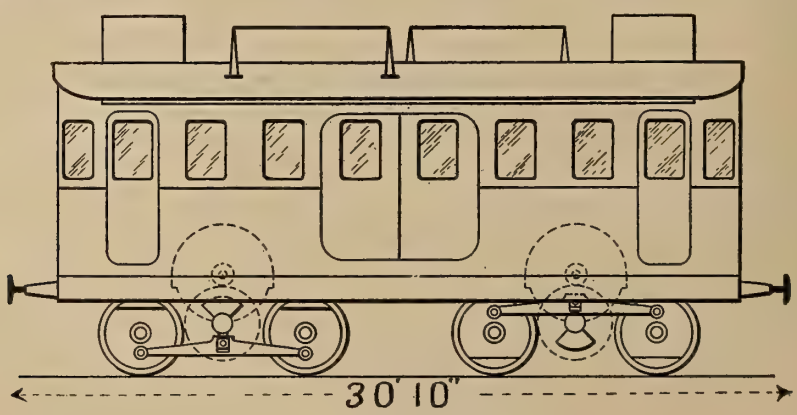


FIG. 25.—OERLIKON SINGLE-PHASE LOCOMOTIVE, SWISS FEDERAL RAILWAYS

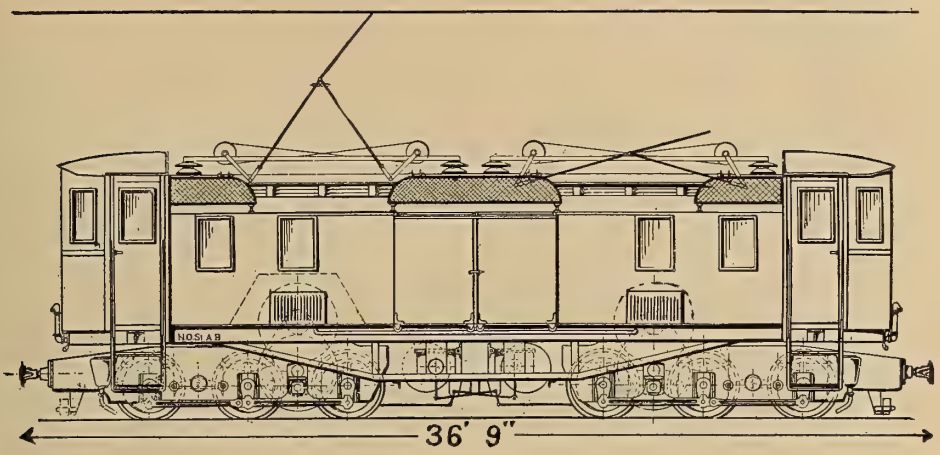


FIG. 26.—SIEMENS-SCHUCKERT NARROW-GAUGE LOCOMOTIVE, ST. POELTEN-MARIAZELL RAILWAY

be termed the 4 + GM, 4 + GM type. Locomotives of the 6 + GM, GM + 6 type, with somewhat similar gearing, are now under construction by the Siemens-Schuckert Company for the narrow gauge 750 millimetre mountain railway from St. Pölten to Maria Zell, in Lower Austria. In this case six-wheeled bogies are used, the six drivers of each bogie being crank-driven from a geared motor (Fig. 26).

The first gearless, crank-driven locomotives were built by Ganz & Co., of Budapest, for the Valtellina Railway in 1903. The mechanical arrangement was designed by engineers of the Adriatic Railway (now the Italian State Railway), among other reasons to obviate the inconvenience of pressing off and on a driving wheel when a gearless motor required repair. Fig. 13 shows the locomotive, type 2, 6 + 2M, 2. This class, with a pony truck at each end, has a total weight of 62 tons, with 42 tons on the six-coupled drivers. The first of the class were fitted with two double motors of the three-phase type. Each double motor is fitted

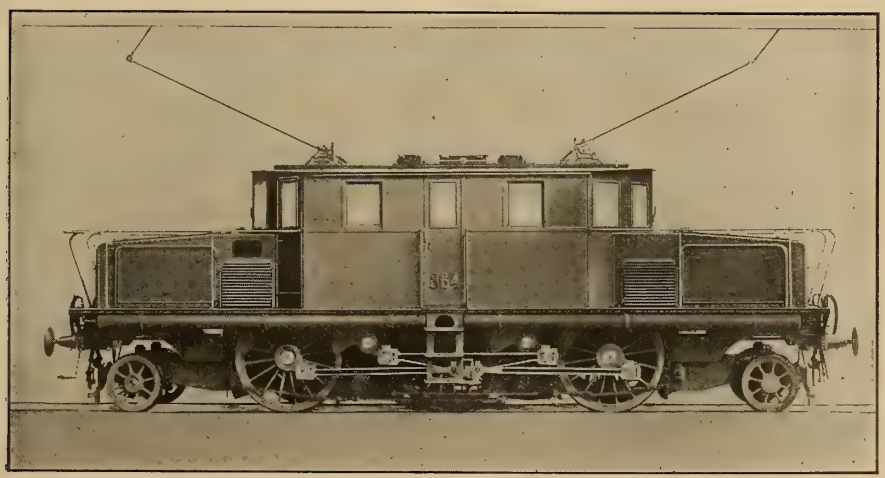


FIG. 27.—BROWN-BOVERI SIX-COUPLED, THREE-PHASE LOCOMOTIVE, SIMPLON TUNNEL RAILWAY

FIG. 28.—BROWN-BOVERI EIGHT-COUPLED LOCOMOTIVE, SIMPLON TUNNEL RAILWAY

with two separate rotors on the same shaft and two stators alongside one another, one being wound for high pressure and the other for low pressure. For speeds up to 32 kilometers (20 miles) per hour, the two sections are run in series, and for higher speeds up to 64 kilometres (40 miles) the high-tension section is used alone. In order to give flexibility, the crank-pins are turned with spherical faces and not cylindrical. Four further locomotives were built by the same company and set to work in 1907. In this later type two motors are fitted, one of 1,200 horse-power with 12 poles, and one of 1,500 horse-power with 8 poles at starting, and up to 15 M. P. H.—the lowest running speed—the two motors are run in series; at 26 M. P. H. the 12-pole motor is used alone, and at 40 M. P. H. the 8-pole motor is worked alone. Liquid resistances worked by compressed air are used for regulating purposes. The motors are wound for three-phase current at 3,300 volts.

Somewhat similar locomotives, built by Brown, Boveri & Co., of Baden, were set to work in 1907 to haul heavy goods and passenger trains through the Simplon Tunnel (Fig. 27). There are two high-tension induction motors, each arranged to give two speeds with one stator winding, the motors being started and regulated by means of resistances. The same makers have recently supplied further locomotives of a more powerful nature, of the 4 + 2M + 4 type (Fig. 28). The four driving axles are driven from two motors through side rods. The two outer axles are hollow, the crankshafts passing through the centre, with a central spherical joint, which allows the wheels to follow the curves. This type of crank axle has been used for steam locomotives. The motors of these locomotives are of the four-speed type, two independent stator windings being used in the same slots, each winding giving two speeds, the working speeds being 16, 22, 33 and 44 miles per hour; at the top speed the two motors develop 1,700 horse-power.

Some remarkable locomotives built

by the Italian Westinghouse Company, Fig. 29, are now being set to work on the Genoa-Busalla section of the Italian State Railways. The gradients are exceptionally severe, and two locomotives will be required for hauling 400-ton trains up 1 in 28.5. The arrangement is 10 + 2M, that is, ten-coupled wheels and two motors. The outer pair of drivers have 200 millimetres (8 inches) side play, and the centre pair have no flanges. The motors are of the three-phase type, with a combined capacity of 2,000 horse-power, with speeds of 14 and 28 miles per hour. The use of three-phase motors will enable descending trains to pump back power onto the overhead line and reduce the load on the steam-generating station.

By the use of dummy crankshafts it has been found possible to raise the position of the motors, making them more accessible, and, at the same time, raising the centre of gravity of the locomotive. Fig. 14 shows the 2, M + 6 + M, 2 type of locomotive being built by the Siemens-Schuckert Werke for the Wiesental branch of the Baden State Railways, near Basel. Fig. 30 shows some details; with this construction the motors can be lifted off the frames by means of an overhead crane.

This same general type has recently been taken up in America. Fig. 31 shows an experimental locomotive built in 1908 by the General Electric Company and the American Locomotive Works. The first trials were carried out with two 400 horse-power motors, but the general design is for two 800 horse-power motors. The same general type is to be used by the Allgemeine Companie for an experimental locomotive to be used in the South of France (Fig. 32).

A number of very heavy locomotives have recently been supplied to the Pennsylvania Railroad Company by the American Westinghouse Company in conjunction with the Baldwin Locomotive Works for hauling trains through the New York tunnel section. Two units, type 4, M + 4, each with a separate cab, are coupled together, one 2,000 horse-power, direct-current limit motor being coupled to four drivers, with a weight of

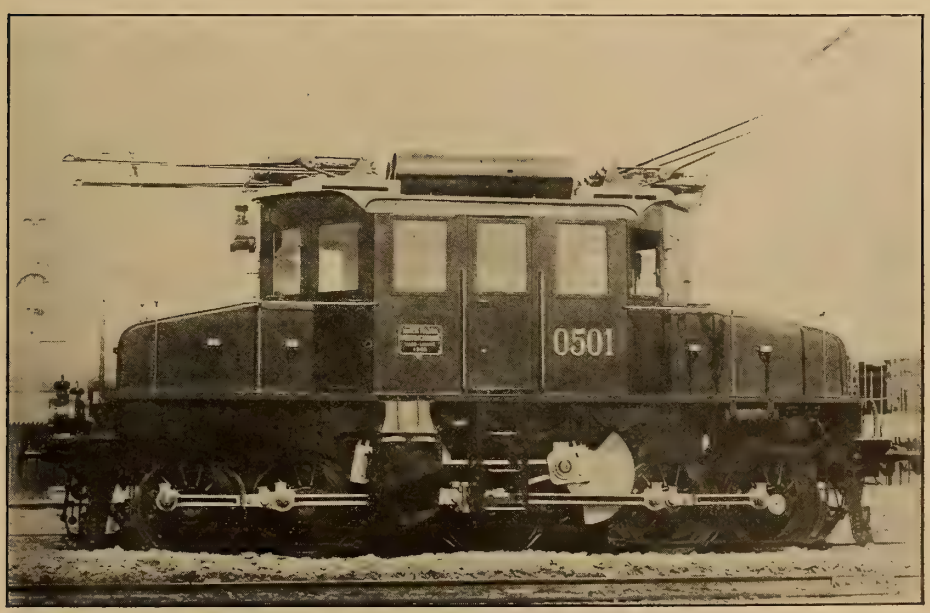


FIG. 29.—WESTINGHOUSE THREE-PHASE GOODS LOCOMOTIVE, ITALIAN STATE RAILWAY

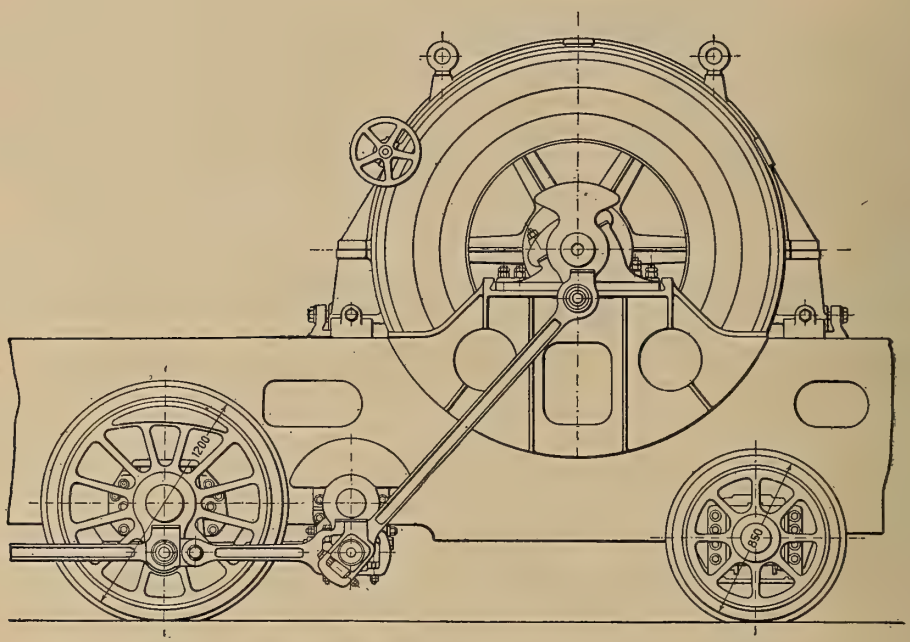


FIG. 30.—CRANK-GEAR SIEMENS-SCHUCKERT LOCOMOTIVE, BADEN STATE RAILWAY

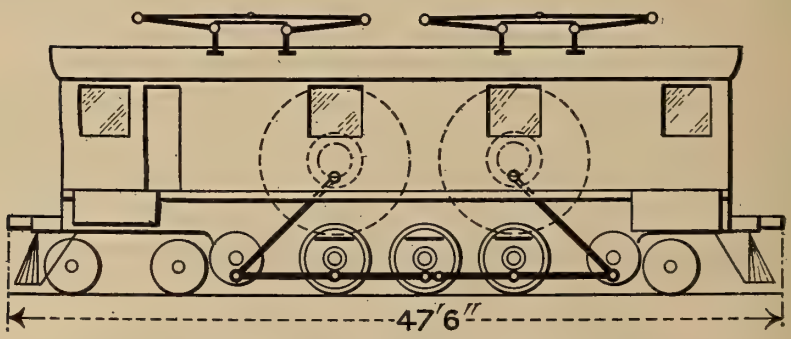


FIG. 31.—GENERAL ELECTRIC COMPANY EXPERIMENTAL LOCOMOTIVE

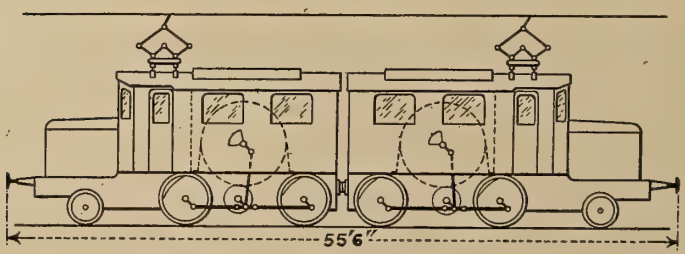


FIG. 32.—A. E. G. LOCOMOTIVE UNDER CONSTRUCTION FOR THE BERNESE ALPS RAILWAY

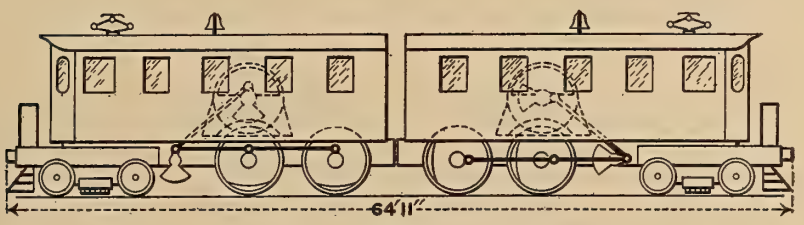


FIG. 33.—A. E. G. DOUBLE-UNIT TYPE LOCOMOTIVE

23 tons on each pair, which is above the European. Each double unit is capable of handling a 500-ton train on a gradient of 1 in 50. In order to make the motor accessible, the cab can be lifted off bodily. Some locomotives have been designed by the Allgemeine Companie with the dummy crankshaft between the drivers. Fig. 33 shows a double-unit type designed for a railway in the Bernese Alps.

The first locomotives were fitted with controllers of the same general type as those in use on tramways, but as the power was increased heavy currents had to be used, and controllers got very clumsy. To obviate this, in nearly all recent cases some form of relay or unit-switch gear is used. This can be operated by low-pressure currents, compressed air, or a combination of both. The usual arrangement consists of a series of switches or so-called contactors, operated by means of a master controller, the various steps in the switching in and out of coils, armatures, resistances or transformer tappings being made by turning the controller handle from notch to notch. Suitable interlocking gear is usually fitted to prevent short circuits in the event of a contactor failing to open when required. The system is the same as that in use for multiple unit trains. The present-day use of electric and pneumatic relays for actuating, switching, safety and other appliances has been largely due to the pioneer work of the General Electric and Westinghouse Companies in America, and Ganz & Co. in Europe.

With modern high-powered traction motors, considerable heat energy has to be dissipated from a small surface in a confined space, due to the various motor losses. Ventilating grids have been used, but they tend to choke with dust, and little circulation is produced, and in most cases of large powers some form of blower is used to blow air through the casings and keep the temperature down.

As a contrast, the heating of electrically-hauled trains is a serious question, especially in cold climates. Electric heating is inefficient, very expensive, and is usually impracticable with through-running coaching stock, so that in a number of cases abroad steam boilers are carried in the cab to heat the train.

The electric traction of heavy main-line passenger and goods trains has made remarkable progress in the last few years, especially over sections where there are excessive gradients or long tunnels, and it is likely to be used in the near future over highly congested sections as an alternative to widening. The problem of general electrification is, however, by no means solved, and great advances must be made in the generation, transmission and application of power before the steam locomotive can be permanently and generally replaced by the electric locomotive.

In conclusion, the author must thank very heartily those firms and engineers that have so kindly assisted him in preparing this article by supplying him with illustrations and particulars.

March 1910

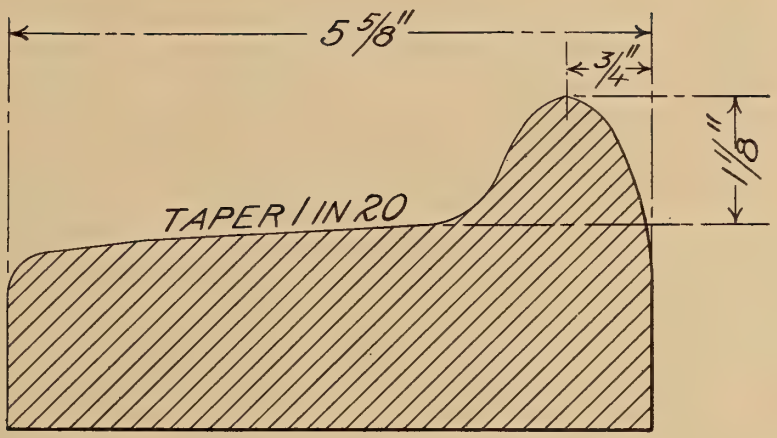
CAR WHEELS

By George L. Fowler

SOMEONE once remarked, with the warranted exaggeration of enthusiasm, that the flange of a car wheel was the most important invention in the records of human achievement. That it has been of inestimable value there is no doubt, and that the whole structure of the wheel has received as much or more attention than any other detail of the car in the development of the railroad is equally certain. Roughly speaking, there are about 2,250,000 freight cars at present in service on American railroads. Each one of these is carried by at least eight wheels whose standard diameter is 33 inches, so that the total number of wheels in service is in the neighbourhood of 18,000,000, and their value, at the lowest possible estimate, $180,000,000.

This refers almost exclusively to the cast-iron wheel, which is still the one that is the mainstay of freight work, and which, until a few years ago, was the only one to be found under either passenger or freight cars. In short, it was upon the cheapness with which the cast-iron wheel could be made that the very existence of many American railroads depended. Its construction was fostered by the remarkably pure ores that were easily available, as well as the supposedly inexhaustible supply of timber from which the charcoal for smelting purposes could be obtained. This combination made it possible to put an exceedingly high grade of iron upon the market at so low a price that it could be used for car wheels at a profit, and the fame of the old charcoal Richmond and Salisbury iron still marks the synonym of excellence. They possessed the necessary properties for giving a good chill or hardened surface for the tread and great strength in the body of the wheel.

In the developing days of the art of wheel making the manufacturers whose reputation was the best and whose name upon the product was the hall-mark of guaranteed excellence, guarded their processes very carefully, and conveyed the idea that the making of a good wheel required an amount of skill far in excess of the realities of the case so that they kept their trade secrets securely locked within their bosoms. They undoubtedly believed what they preached; but their methods were far from scientific, and their success was based solely upon their care in the selection of stock, attention to melting and pouring, and a choice of patterns that would minimize the internal stresses set up in the metal in the casting and cooling. Indeed, after the proper mixture had been obtained, there was a great amount of work expended in the development of the pattern. Almost every conceivable shape and combination of shapes to connect the rim with the hub were tried, and the end is not yet. But, many years ago, the double-plate wheel, a section of which is shown in the engraving, came to be the established standard, and is now in universal use, except in the case of a few spoke wheels put in special places. The shape of the plates and of the brackets that support and stiffen it are still the object of experiments, but in all of its essential details the cast-iron wheel reached its maturity in 1886, when a standard form of tread and flange

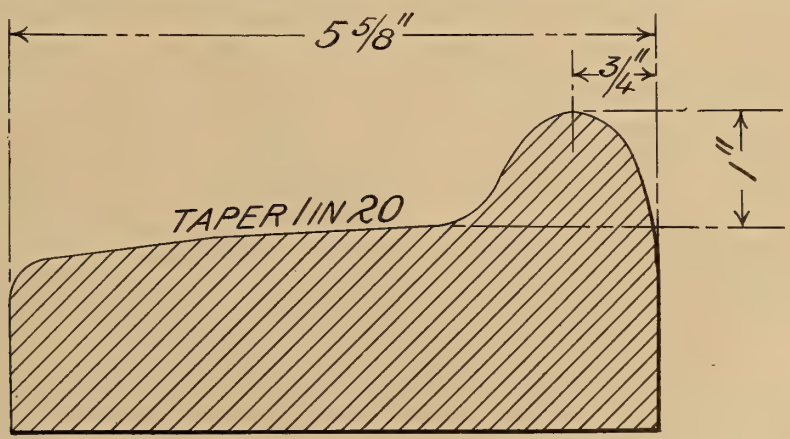


STANDARD AMERICAN TREAD AND FLANGE, 1886-1909

was adopted. This was done after several years of discussion and has remained until the present time. It is only within the past year that any modification of this original standard has been made. The flange had a height of 1⅛ inches, with a gothic crown and a thickness of 1¼ inches at the top of the root curve. The change made cuts the height down to 1 inch, with a corresponding change in the details of the dimensions, but retaining the thickness the same.

In all this the mechanical structure of the wheel has been the feature upon which dependence has been placed, and this has been determined by a few simple tests used to ascertain as to whether the metal was of a suitable quality to meet the conditions of the work that it had to do.

In this connection there was little real information. The early manufacturers knew little or nothing, apparently, of the physical or chemical quality of their output. A chemist in connection with a wheel foundry was absolutely unknown, and even as late as 1890 one large maker at least, whose reputation was of the best, had not the remotest idea of the physical characteristics of the metal in his wheels. He bought certain brands of pig-iron, used certain percentages of these, added another percentage of scrap wheels, and there stopped.



STANDARD AMERICAN TREAD AND FLANGE, ADOPTED 1909

Now these wheels were designed for use under cars of small capacity, and, at the time the standard tread and flange were adopted in 1886, a car capable of carrying 50,000 pounds was rated as a large one; whereas the early development of the wheel and its introduction into universal service was under cars of but 20,000 pounds capacity, wherein the empty weight was about as much more. Under these conditions the service was eminently satisfactory. With such loads, wheels from makers of repute would go under cars and remain there indefinitely, disappear from the records and outwear the car.

But in the early seventies, when the weights of passenger cars began to be increased and the speed of trains to be raised, there arose a feeling of insecurity in the cast-iron wheel, and a steel-tired one was substituted therefor. The substitution was carried forward very rapidly: sometimes for advertising purposes, sometimes as a matter of policy to avoid excessive damages in case of accident and for the increased safety that was thus insured. It was not many years before the steel-tired wheel was established as the standard for passenger-car work on nearly all roads. A few continued to use cast iron, however, long after others had fallen into the steel-tired line, and, indeed, this practice is still to be found. But it is interesting to note that it is seldom used under passenger cars, nor has it been for many years, except where it is made by the road applying it, so that the consumer has a complete control of every step in the making.

At present it may be taken as a general consensus of opinion that the cast-iron wheel is not suited for use under a passenger car. The same development has been going on, though more slowly, for freight cars.

In the days when the freight car, with its load, weighed 40,000 pounds at the outside, the strength of the cast-iron wheel was so much in excess of any stress that was apparently being applied to it that this detail was given no consideration whatever, because it required none, as the factor of safety was so large that no one knew what it was, and breakage was rare. But these small weights are now of the past and are not known; the 10-ton car was relegated to the scrap heap a generation ago, and in its stead we have gradually added capacities, raising them from 20,000 to 30,000, 40,000, 50,000, 60,000, 80,000, and finally to 100,000 pounds, without adding very much, if anything, to the strength of that crucial point—the tread and flange.

That the wheel was worthy of itself and of its reputation is vouched by the fact that, designed originally for such light loads, it has been able to carry these successive increments of increased weight without serious failures. Apparently no more trouble is experienced under cars of 60,000 pounds capacity than in the old days of one-third this load. Even at 80,000 pounds the trouble is not serious enough to attract attention, and many railroad men claim that there has been no increase of failures, as compared with the 60,000 pounds cars. But when the load was increased to 100,000 pounds, with the possibility of an increase of 10 per cent. overload under the rules of loading, raising the total weight of the car and its lading to 150,000 pounds, trouble cropped out at once, and the wheel has become a source of anxiety to the operating and mechanical officers who are using it in such places.

Of course, there are differences of opinion as to why it should fail. The tread and flange are the same as in the early wheel, but the rim, plates and hub have been thickened, so that the weight has been increased from 450 and 500 pounds to 600 and 700 pounds and even 750 pounds each. In addition to this, there has been such a readjustment of the shape and proportions of the brackets at the back beneath the tread that there is no doubt of the probability that internal stresses, due to cooling, have been greatly reduced. But of this

there are no data. We simply know that internal stresses and strains do exist in the metal, without the slightest inkling as to their intensity or character. It is not probable, however, that these internal stresses are directly responsible for the failures that have occurred, though it is equally probable that they have been contributory causes. One of the principal reasons that have been assigned for wheel failures under cars of high capacity is that of long-continued brake application, though this pressure has not increased as much as the weight of the cars and the loading. In the days of the light cars and the application of the brakes by hand there is no record as to what brake-shoe pressures were used; but it is certain that many trains were held on long grades by the brakes of a few loaded cars, set up by a powerful trainman as hard as he could pull with a club, so that shoe pressures must have been very much in excess of the 70 per cent. of the light weight of the car that was afterwards adopted as standard with the introduction of the air brake. This means that, on a car of 100,000 pounds capacity, weighing 40,000 pounds empty, the brake-shoe pressure will be 3,500 pounds on each wheel, as against 3,375 pounds for a car of 60,000 pounds capacity. When running at a speed of ten miles an hour down a long grade, this pressure generates a great amount of heat that must be dissipated by the shoe and rim. Such a heating of the rim weakens it, and the peculiar form, with its variations of thickness and texture of the metal, set up stresses that may well account for the characteristic cracks that appear at the root of the flange and the breaking off of the same that is productive of an almost certain derailment.

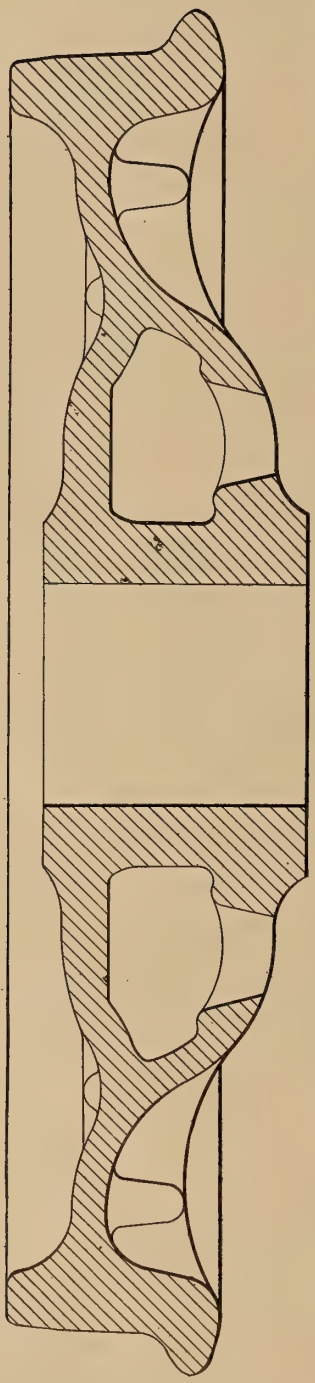
This view that the brakes are responsible for the failure is strengthened by the fact that far more trouble is experienced on mountain roads than upon level ones.

We know, too, very little regarding the physical stresses due to running to which car wheels are subjected. But that little goes to show that they are far from being a negligible quantity. The investigations that have been made indicate that the lateral thrust of the wheel against the rail varies as the speed and inversely as the radius of curvature of the track, and that, under ordinary operating conditions, this may rise to 30,000 pounds. Of course, the strength of the flange shows wide variations, and it has been found to range from 40,000 pounds to 125,000 pounds for shear. If the lower figure obtains and the wheel is weakened by the heat of the brake-shoe, and it then receives a heavy lateral blow, a fracture is the almost certain result that will follow.

When we further consider the effect of stiff or closed springs in the support of the load, the influence of track that is out of surface or alignment, and the severe blows that are received in striking guard rails and crossings at high speeds, it is plainly evident that the stresses to which car wheels are subjected are beyond the bounds of mathematical calculations, and can only be determined by dynamometric investigations on the ground. And as for the failures, the wonderful part is, not that they occur, but that so brittle and weak a metal as cast iron can be put into shape to withstand these excessive stresses.

Having now considered the physical conditions under which a wheel must do its work, what has been done to make it equal to the task?

Recognizing the severity of the blows that will be received, the Master Car Builders' Association specifies a minimum variation in the diameters of wheels; that the plates and hubs shall be of a clean gray iron; that the depth of the white iron in the chill shall not be more than 1 inch or less than ½ inch; that two wheels from each lot of 100 wheels shall be tested, one by the drop test, wherein



SECTION OF CAST-IRON WHEEL

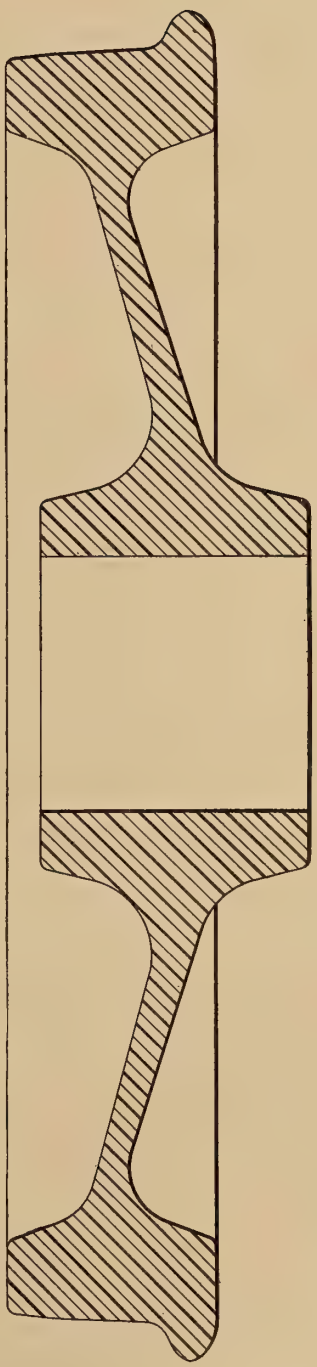
a weight of 200 pounds shall be let fall upon the hub from a height of 9 feet without breaking it, the number of blows to be dependent upon the weight of the wheel, and that the other shall be laid in sand and a channel 1¼ inches wide and 4 inches deep be cut around the tread, and that this channel shall be filled with molten metal, and that two minutes later the wheel must still be intact. These to represent the stresses due to service and brake-shoe application.

Although the tests are severe and generally efficient, they cannot be absolutely depended upon to weed out weak wheels, so weak wheels may occur in every lot because conditions of manufacture cannot be kept identical for every wheel for even a single heat.

It is only in comparatively recent years that the chemistry of wheel making has received the attention that it deserves. As already intimated, the early manufacturers worked more by the rule-of-thumb than from scientific reasoning, and had little information regarding the influence of the various impurities on the metal, depending upon the reputation of the brands of iron that they bought to hold their own.

One of the first to recognize the importance of this was the Pennsylvania Railroad, where, about 1874, wheels began to be cast under the Hamilton patent, which was based on the use of a certain percentage of steel rails in car-wheel mixtures. The purpose of this was to reduce the silicon content. Although sulphur and manganese have a hardening effect on cast iron, it is the silicon that is really the controlling element in the matter of the depth of chill; and if it is too high, no chill can be formed. It is, therefore, necessary that low-silicon irons should be used. But as the production of such iron was difficult, the Hamilton process merely introduced a low-silicon metal into the mixture, which cut down the percentage contained and secured the desired results.

The value of the use of rails having been demonstrated, it has been continued to the present time. With the production of lower-silicon irons the percentage of rails has been decreased, and, with a more thorough understanding of the chemistry of the process, the indispensable portion of charcoal iron has been done away with. The ultimate reason for this dethroning of the charcoal iron lies in the fact that the iron is melted in a coke furnace and, coming into contact with the fuel, the iron is influenced accordingly, which would not be the case at all were the melting to be done in an air furnace, where the metal and the fuel are not brought together. The value of the iron lay in the freedom from sulphur, which was injured by the use of coke in the cupola. So that now the basis for car-wheel mixtures in plants that are pursuing the latest methods is to analyze samples from every carload of iron that is received, pile each such carload separately, and make up the charges from the chemical analyses solely. In this the silicon and carbon alone are taken into consideration, care being observed, of course, that, in the purchase of the material, irons high in sulphur and phosphorus are not bought. Further than this, it is the combined carbon and not the total carbon that is considered. Experience has shown that the best results, both for depth of chill and strength of the gray iron metal are obtained when the silicon content is from .53 to .55 per cent. and the combined carbon from .70 to .78 per cent. Cupola practice has also shown that the metal, in passing through it, will lose about .10 per cent. in silicon and gain about the same in combined carbon. Hence, in preparing the charges, it is well to so proportion the metals that they will give an average of about .65 per cent. silicon and the same of combined carbon, when the output will be found to contain about .55 per cent. silicon and .75 per cent. combined carbon.



SECTION OF SOLID STEEL WHEEL

Now, although this may be done with the utmost care, the chemical reactions of the cupola are still to be reckoned with. The condition of the coke used, the pressure of the blast, the rate of melting and the variations from the calculated chemical content may make variations in the product that must be met and brought back to the standard requirements as the melting and pouring progresses. This is done by casting test pieces from each pouring. These are broken as soon as they are cool and, if the chill is below the standard, the corresponding wheels are broken up and a change made in the chemical composition. To do this, a pile of short ends of steel rails and ferro-silicon is kept at hand. Should the test pieces show that the chill is becoming too deep, some ferro-silicon is added. This liberates a part of the carbon and increases the silicon content, thus introducing a softening element that reduces the chill. If the chill is too shallow, a piece of steel rail is added to the ladle. This lowers the average silicon content, by which the softening element is decreased and, at the same time, the percentage of manganese—a hardening element—is increased.

In addition to this watching of the iron, the fuel is subjected to a no less rigid scrutiny. The prime requisites of a good melting coke are that it should have the strength to carry the weight of the charge, be high in fixed carbon and low in sulphur. These are properties that can be readily met by American ovens; and if a foundryman uses coke with more than .75 per cent. sulphur, he has no one to blame but himself.

Again, the rate of melting and the temperature of pouring are important. In this the foundryman must steer a straight and narrow course. Iron for wheel work must be melted hot, and yet, while hot melting adds to the ability of the wheel to withstand the thermal test, it is dull-melted iron that is best capable of resisting the drop tests. It is, therefore, necessary to watch the metal as it goes into the ladle and to make such adjustments and changes of blast pressure as may be required by the changing conditions of the bed of iron in the cupola.

There is one more step in the process that needs a word. When the molten metal is poured into the mould and comes in contact with the cold iron of the chill ring that is to form its tread, it is cooled and solidified with great rapidity, and this causes it to become very hard. This chill is the crux of the wheel; and unless it is of the requisite hardness and penetrates to a sufficient depth to give the wear required, the wheel will have a short life. If the wheel is made in a solid ring, it contracts as it cools, and the chill ring expands as it becomes heated, with the result that the surfaces of the chilling ring and the wheel tread separate. This reduces the chilling effect, and with it the depth of the white or hard metal. To meet this difficulty, numerous designs of contracting chills have been used, in which the metal of the ring follows up that of the wheel and thus produces maximum results. The form now used is that of a broad ring with a number of inwardly projecting segments. As these segments become heated by the molten metal, they expand inwardly from the solid ring and keep in contact with the wheel.

It has been shown that the cast-iron wheel is the cause of considerable uneasiness in the minds of railroad officials when it is used under high-capacity cars. As to the reasonableness of this uneasiness there are two opinions.

Railroad companies that are making their own wheels are very emphatic in the statement that they are making as good an article as can be made under the conditions of our present knowledge. No one presumes to say that the best possible wheel

is being made, because that would cut off all expectation of future improvement. Therefore, the uneasiness is reasonable. The wheel makers, on the other hand, claim, with almost absolute unanimity, that they could make a better wheel if the railroads would but pay for it, and that the purchasers are getting all that they are paying for. To which the retort comes: "Then why do you not offer a better wheel and make a corresponding guarantee?"

Attempts are being made along this line and experiments are constantly in progress looking towards the betterment of the product. Nickel has been added to the metal, with laboratory results that are very encouraging, and titanium, the scavenger, has also been used; but in neither case have the wheels been in service for a sufficient length of time to give definite results or to warrant extensive operations in the way of an adoption of either process.

As for deterioration of quality, of which so much is heard, there is probably no foundation in fact for such statements. To be sure, the present-day wheel does not have the same length of life as the old charcoal iron wheel of the early seventies; but it does not have the same amount of work to do. Then it carried a load of 5,000 pounds; now it carries one of 20,000 pounds; and it is safe to say that the stresses to which it is subjected have increased more than four-fold of the weight; so that the past records of the good, old wheels are useless as a basis of comparison, even if we had any authentic records of what had actually been done, which we have not.

The problem is a serious one from a financial standpoint, but not from a mechanical one. It is of the utmost importance to the railroad companies that a thoroughly safe and reliable cast-iron wheel shall be produced at a low cost. This is evidenced by the number of wheels in service, and the proportion under cars of 100,000 pounds capacity is constantly increasing, for the whole question of cheap transportation depends upon the utilization of large units. Hence, the large cars will not be abandoned because of the weakness of the wheel, but a wheel must be produced that will meet the requirements.

Mechanically, the present solution has been found in the solid steel wheel. The steel-tired wheel has been in use under the heaviest classes of rolling stock, locomotives, tenders and passenger cars for many years. The speeds have been excessive in the extreme; so much so that 50 and 60 miles an hour are considered moderate; 75 miles is hardly noticed, and it is only when 80 is touched that attention is attracted. In all of these years of service the failures of steel tires have been so small as to be negligible. In strength, they are possessed of from six to ten times that of a cast-iron wheel, so that, as far as safety is concerned, the article to insure it is at hand. The only reason why steel-tired wheels are not used for freight work is that of expense. They cost from two and a half to three times as much as the cast iron, and it is to meet this objection that the solid steel wheel has been developed.

Preceded by a long series of failures because of difficulty with the metal, the solid steel wheel—that is, a wheel made in one piece—can now be made and the metal secured that will meet the steel tire on every test, physical, chemical and microscopical, that can be applied.

With the development and increased demands of the passenger service both in the weights to be carried and the reduction of the rate of wear of the tire, there has been a corresponding improvement in the character of the metal that is used. Twenty years ago the carbon content of acceptable tires was as low as .45 per cent., with a tensile strength of from 85,000 to 90,000 pounds per square inch. This carbon content has been gradually raised and, with it, the limit of elasticity, until now the carbon runs

from .65 to .70 per cent., with an ultimate strength of from 120,000 to 125,000 pounds per square inch, and the limit of elasticity from 90,000 to 95,000 pounds per square inch. These figures can be obtained from tires taken from stock.

In the development of the solid steel wheel as distinguished from the steel-tired wheel, where the tire is fastened to a centre made of cast iron or steel, it has been made the goal to produce a metal that should be the equal of the steel tire, and this has been done. By care in the cropping of the ingots to avoid piping and segregation, by close attention to heating, and by the use of very powerful machinery by which the rolling of the tread may be carried on down to a low temperature, the essentials of a good tire metal have been obtained. These may be put at a high tensile strength and limit of elasticity, a high ratio of elongation before rupture under load, and hardness with the density of fine grain. The chemical features of low sulphur and phosphorus and high carbon are matters of the furnace and the steel maker, and can, of course, be obtained as well in an ingot intended for a solid wheel as for one that is to be made into tires. It was the mechanical features that gave trouble, added to the necessity of producing a low-priced wheel. All this has been done, and a suitable wheel is available.

But, despite the fact that the solid steel wheel is cheaper than the steel-tired, it is still much more expensive than the cast-iron, and if we add 75 per cent. to the cost of the standard 33-inch wheels in our freight service, the investment of American railroads in car wheels alone would jump to at least $315,000,000.

To be sure, these figures are beyond the bounds of possibility, for the cast-iron wheel will never be driven entirely out of the market, even though the future sees no improvement in it, as it gives good service in what we are now pleased to consider our light cars of 60,000 pounds capacity. But there is a crying need for a wheel of cast iron that will be up to the requirements of the 100,000 pounds capacity cars under all conditions of service, and it remains to be seen whether the makers can meet these requirements. They say that they can.

RAILWAY SIGNALING IN AMERICA

By J. S. Hobson

THE term "Railway Signaling" in its broadest sense covers any method for controlling train movements by signs or signals which may be visual or audible.

The object of this article is, however, to treat only of a part of that branch of signaling comprising "fixed signals," or visual signals having a definite location. This branch is usually divided into four classes, namely, block signaling, interlocking, train order signaling and signaling in in which the aspect displayed is never changed, such as whistle posts, station boards, etc. In actual practice these four classes are more or less intervolved, but for purposes of description they can best be treated separately.

BLOCK SIGNALING

Block signaling, or the art of spacing trains, is effected by dividing a railroad into sections, technically known as blocks, and controlling the entrance of trains into such blocks by means of fixed signals located at the entering end on double track, and at both ends on single track.

The simplest method of blocking trains, which is to-day in use on 44,576 miles in the United States, is known as the "Manual" block system. In this system the admission of a train into a block section is controlled by signals actuated manually by the signalman at the entering end of such block on information furnished him through telegraph, telephone or bell code by the signalman at the opposite end. In other words, the signalman at both ends of the block co-operate with each other through some electrical means of information to control the entrance of trains to that particular section of track.

On many roads operating under this system it is the practice to maintain the "absolute" system and allow but one train to occupy a block at a time; but where traffic conditions demand, it is frequently the custom to operate freight trains under the "permissive" system, whereby one train is permitted to follow another into a block under a caution signal or card after a predetermined time interval.

Since the proper operation of the "Manual" system is dependent entirely on human agency, various "Controlled Manual" block systems have been devised to guard against possible errors of signalmen.

A controlled manual system is similar in operation to the "Manual," with the addition of electric interlocking devices between adjoining block stations, which *compel* the co-operation of both signalmen to admit any train to a block. Such a system is shown in Fig. 1.

In this system the operating levers and the mechanical and electric devices which control them are combined in one compact instrument. This instrument is secured to the wall of the office in which it is located, and the mechanical connections between it and the signals it works are attached to one or the other end of the racks operated by the levers. To clear a signal at one of the two stations certain manipulations must be performed by both signalmen conjointly, and the clearing of either signal locks the opposing signal in the "stop" position.

Another "Controlled Manual" sys-

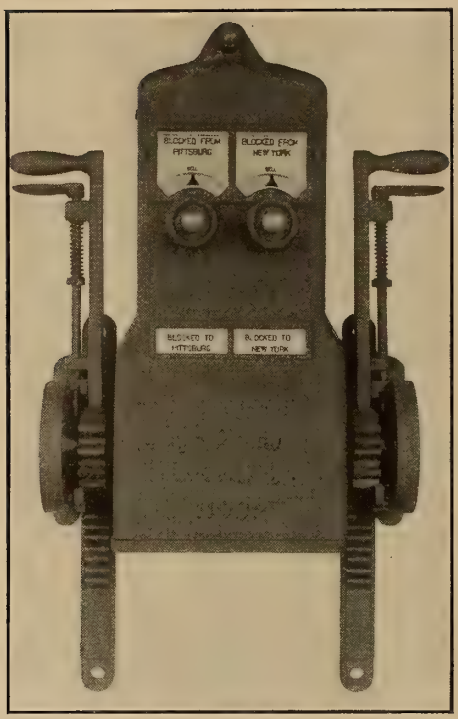


FIG. 1.—ELECTRO-MANUAL BLOCK INSTRUMENT

tem for single-track operation—the electric train staff—has an additional safety feature over the system just described, in that before any train can enter or occupy a block the conductor or engineer must first obtain a tangible right to do so in the form of a token known as the "staff."

The "staff" is a metal rod 6 inches in length and weighing 6½ ounces. One-half of its length is used as a handle and the remainder turned down to rings of different diameters to actuate the locks of the staff instrument (Fig. 2).

One instrument is located at each end of the block and the two electrically connected. Each contains, when first installed, twenty to thirty staffs lying in the vertical and diagonal grooves, from which they can only be removed at the upper end of the former, and then only by the cooperation of both signalmen.

The removal of a staff from either instrument throws it out of synchronism with the instrument at the opposite end, and thus prevents the removal of a second staff from either until the staff removed has been placed in the instrument at the far end of the block or returned to the one from which it was removed.

From this it is apparent that, as no train can enter a block without a staff in its possession and as but one staff can be obtained at a time, the factor of error due to human fallibility is reduced to a minimum.

It is interesting to note that the

FIG. 2.—ELECTRIC TRAIN STAFF INSTRUMENT

FIG. 3.—ELECTRIC HIGH-SPEED TRAIN STAFF

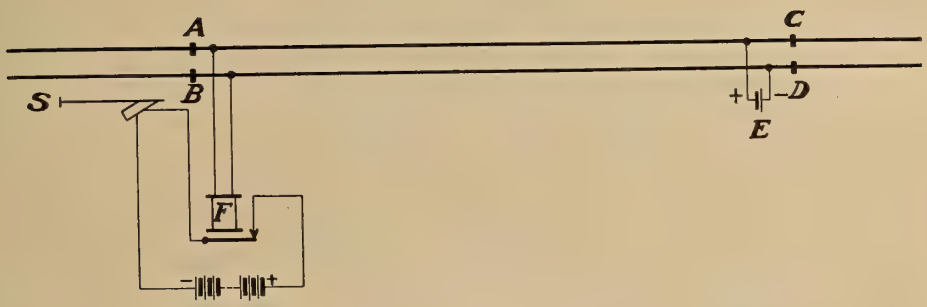


FIG. 4.—EARLY TRACK-CIRCUIT SIGNAL IN THE "PROCEED" POSITION

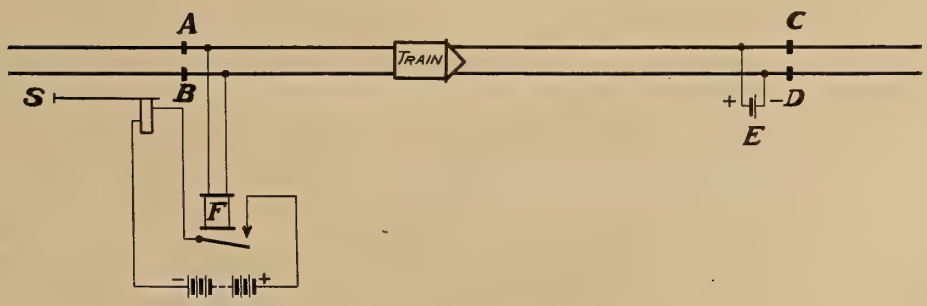


FIG. 5.—ROBINSON & POPE'S SIGNAL IN THE "STOP" POSITION

staff is a veritable key to the block, in that it is used to unlock the signals controlling the entrances to such block and also any switches that may be located therein. The staff can be taken by moving trains without difficulty, being caught by hand at speeds up to 15 or 20 miles per hour and with a device similar to a mail catcher at higher speeds (Fig. 3).

cost of labour, it is not likely that they will ever be used as extensively as those block systems where the control of the signals is effected by automatic means alone.

The first automatic block signals were controlled by "track instruments," or devices by which moving trains automatically opened or closed signal circuits by impact between the

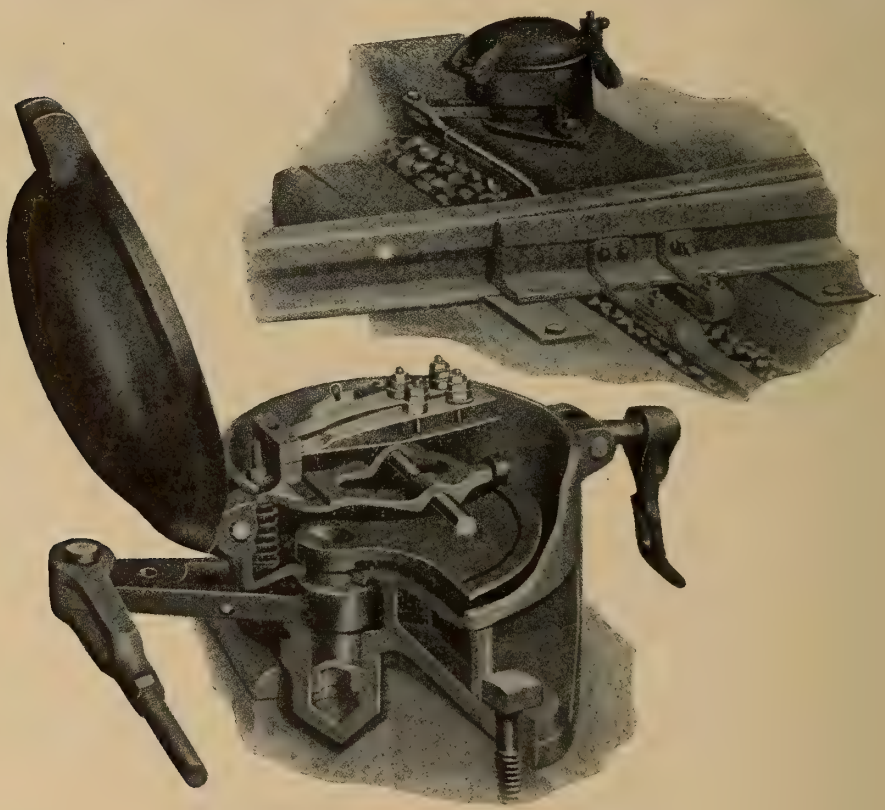


FIG. 6.—VERTICAL ROTARY SWITCH CIRCUIT CONTROLLER

Any controlled manual system may have its factor of safety increased by controlling its signals through continuous track circuit, hereafter described, thereby insuring that such signals will be set automatically to "stop" by a train entering a block and remain in that position as long as the block is occupied. While controlled manual systems are used to considerable extent in the United States, yet, owing to the comparatively high

wheels of the train and a bar or treadle of the instrument. Such systems, however, possess the serious defect that they do not accurately record the condition of the block under all conditions, and their use is now confined to the lighter class of electric railroads, where track conditions do not permit the use of continuous track circuit.

The simplest form of track circuit, invented in the early seventies

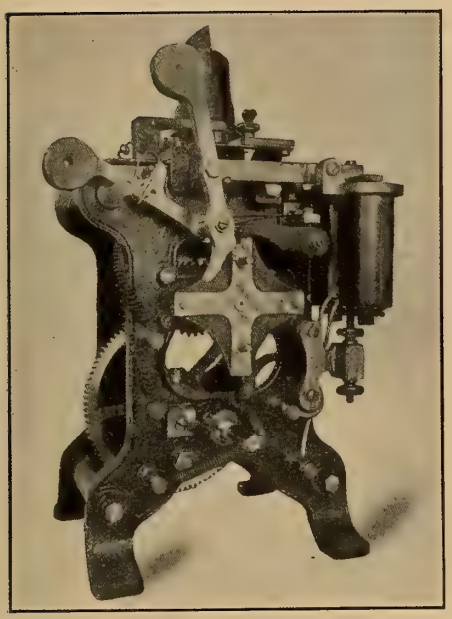


FIG. 7.—ROTATING CLOCK-WORK SIGNAL MECHANISM

by Robinson & Pope is shown diagrammatically in Figs. 4 and 5. The track rails at both ends of the section are electrically insulated from their adjoining rails by special joints *A, B, C* and *D*. To one end of the insulated section thus formed an electrical source of energy (*E*) is attached, usually in the form of a battery of low potential (one or two volts). From the opposite end electric connections run to a relay (*F*) having a resistance of 4 or 5 ohms. The contacts of this relay open and close the controlling circuit of a power-operated signal *S*. When no train occupies the section, the electric current from the battery *E* flows through the upper track rail through the coils of the relay and thence back to the battery through the lower track rail. The energized relay *F* closes the local circuit of the signal *S*, which is thereby moved to the inclined or "proceed" position (Fig. 4).

As soon as the first wheels of a train enter a block, the electric current, following the line of least re-

FIG. 7.—ROTATING CLOCK-WORK SIGNAL

sistance, flows through the wheels and axles from the upper to the lower rails instead of through the coils of the relay *F*, which, being thus, de-energized, allows its contact to open. The opening of this contact de-energizes, in turn, the magnet holding signal *S* in the "proceed" position and, consequently, the signal assumes the horizontal or "stop" position by gravity (Fig. 5), and so remains until the last wheels have left the block, at which time the signal again indicates "proceed."

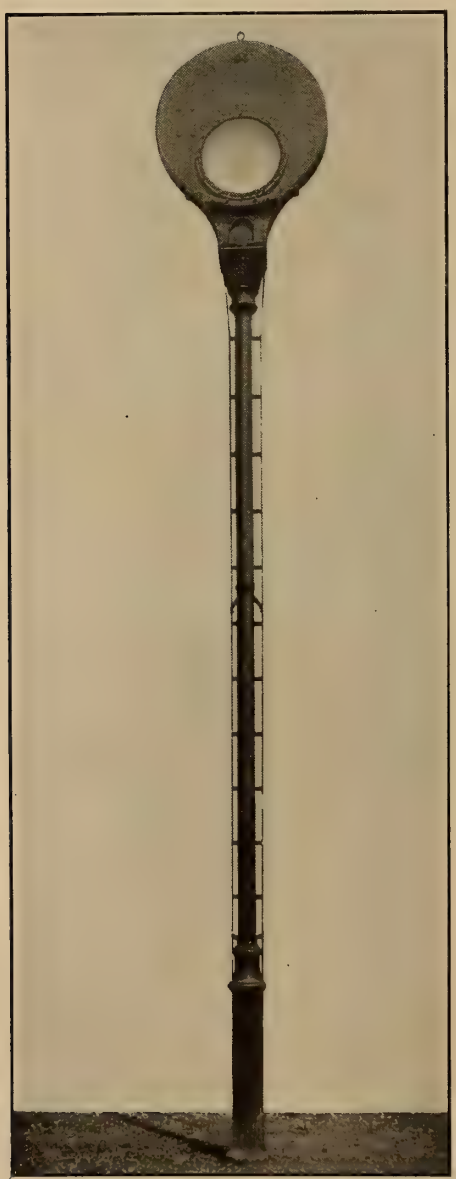


FIG. 8.—ENCLOSED DISC SIGNAL

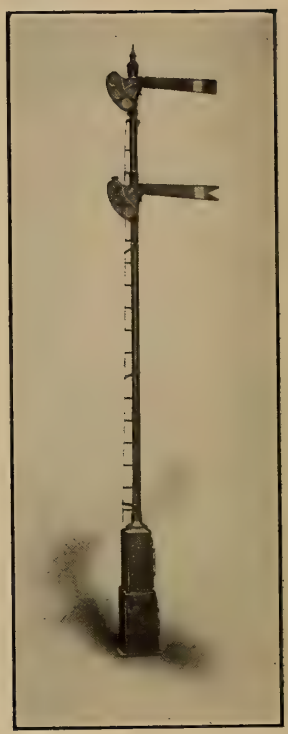


FIG. 9.—ELECTRIC SEMAPHORE SIGNAL

By the use of special circuit controllers, known as "switch boxes" (Fig. 6), the opening of the points of any switch in an automatic block section instantly causes the signal at the entrance of that block to indicate "stop"; also, the breaking of a rail under a train will, by interrupting the continuity of the track circuit, prevent the signal from returning to the "proceed" position after the train has passed out of the block.

The maximum length of a track circuit, except under unusually favourable conditions, is limited to about a mile; but as any number of sections can be relayed in succession, automatic signals can be spaced whatever distance apart is demanded by traffic conditions.

By modifications of this compara-

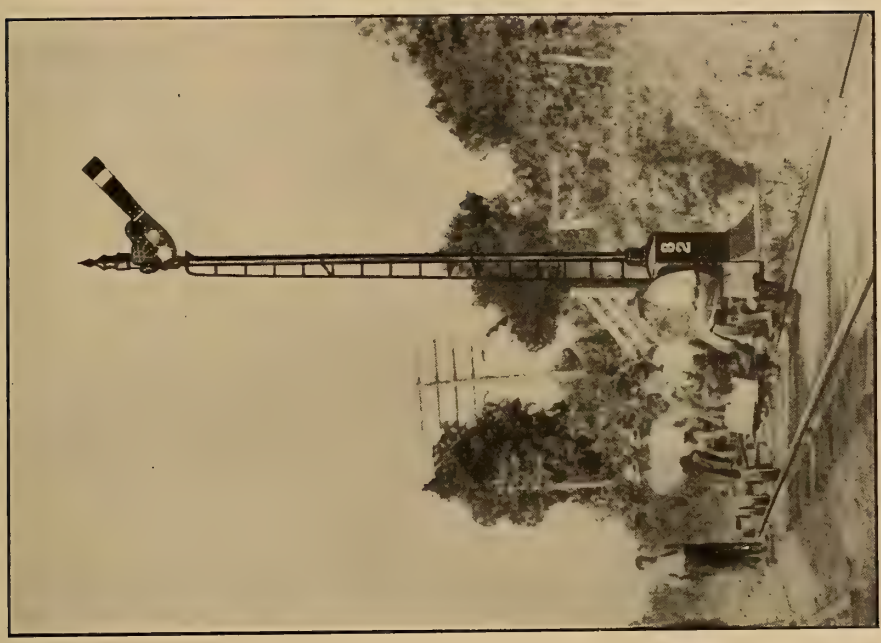


FIG. 11.—"CAUTION" POSITION OF THE SAME SEMAPHORE SIGNAL

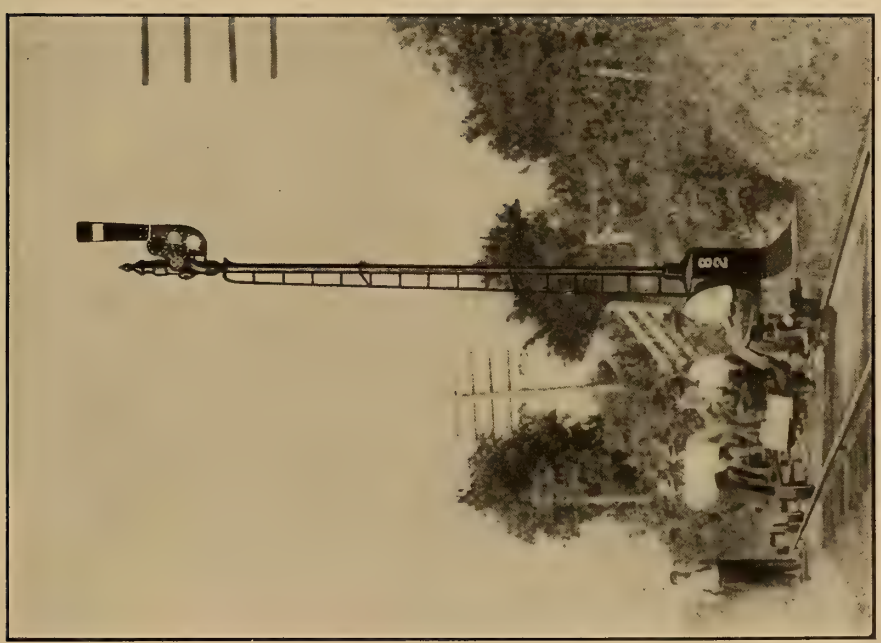


FIG. 10.—"CLEAR" INDICATION OF THREE-POSITION ELECTRIC SEMAPHORE

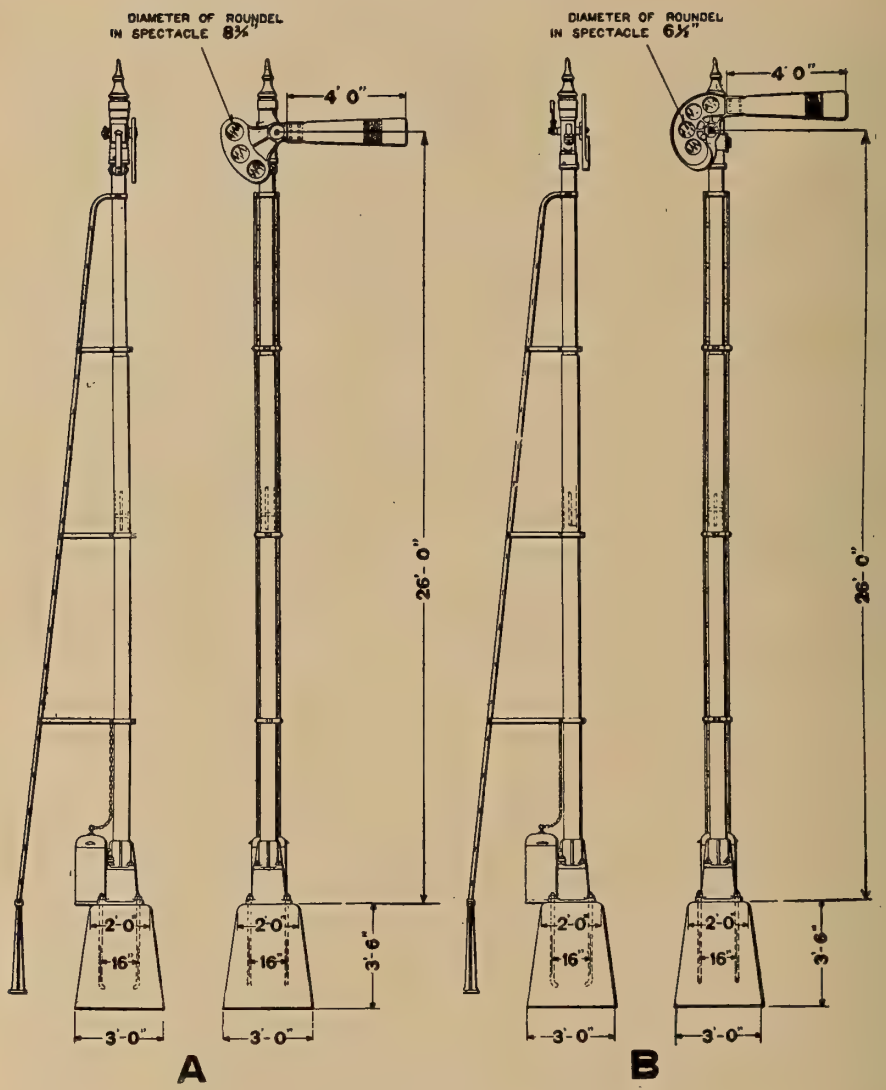


FIG. 12.—ONE-ARM ELECTRO-PNEUMATIC SIGNAL

tively simple device more than 12,000 miles of railroad in the United States are already protected, and the present year will see upwards of a thousand more.

Many forms of power-actuated signals are used for automatic blocking, the older ones being the rotating clock-work signal (Fig. 7) and the enclosed disc (Fig. 8). Both of these are "color signals" in that the display of a white disc by day and a white light by night indicates "proceed" and a red disc and light "stop." Present-day practice has, however, unanimously decided in favour of the semaphore type of signal (Fig. 9), which, while also a color signal at night, displays the daylight indications by the position of the arm with relation to the post, irrespective of its color.

In the past three years the tendency of leading railroads has been to adopt a semaphore giving the "proceed" and "caution" indications by inclin-

ing the arm above instead of below the horizontal, as heretofore (Figs. 10 and 11). The advantages of this "upper quadrant" semaphore are readily apparent when it is considered that the natural tendency of such an arm is to return to the horizontal or "stop" position by gravity without the necessity of employing artificial counterweights, as in the older "lower quadrant" types. Furthermore, any accumulation of ice or snow on the arm tends to assist it in returning to the "stop" position, the reverse being true in the older signals. Semaphores displaying three distinct indications—"stop," "caution" and "proceed"—by means of one arm or "three-position signals" (Figs. 10 and 11), are superseding the former two-position signals, because by reducing the number of arms and lights for a given indication they can be more readily understood by enginemen. There are three types of power-actuated semaphores in general use: the electro-pneumatic (Fig. 12), the electro-gas, and the electric motor, one form of which is shown in Fig. 13.

The electro-pneumatic signal is operated by compressed air at a pressure of between 80 and 100 pounds per square inch admitted to and released from a single-acting cylinder by means of an electrically-controlled valve (Fig. 14). This is the oldest type of power-operated semaphore, having been invented in 1883. It is largely used, particularly on four-track railroads having frequent and heavy traffic, where the cost of the pipe line and compressing plant is divided amongst a comparatively large number of signals per mile. For simplicity, reliability and durability it has no equal.

The electro-gas signal is similar in general principles to the electro-pneumatic, except that the motive power is liquid carbonic acid gas instead of compressed air, and the signal is held in the "clear" and "caution" positions by an electric latch, the gas being used only to move the arm from the horizontal to either of these positions.

There are a number of electro-gas signals in successful use; but by far the most popular automatic block

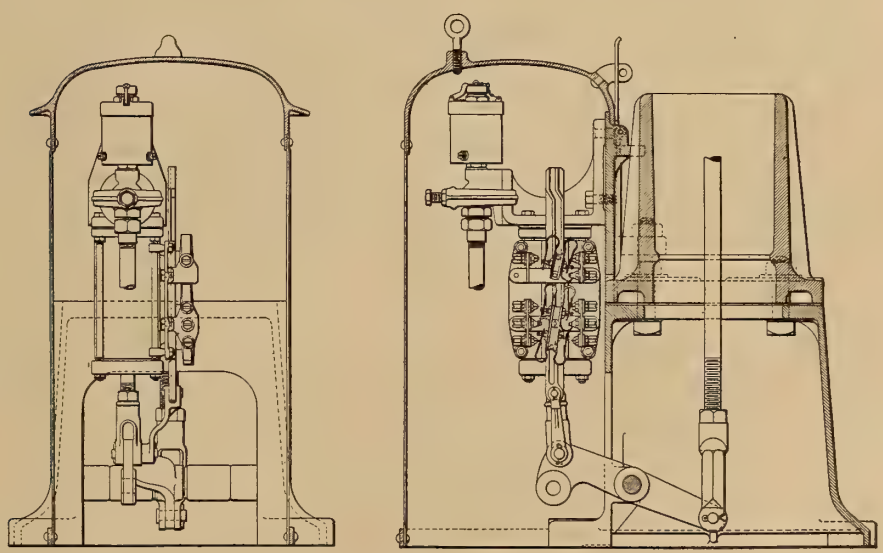


FIG. 12.—VIEW SHOWING APPLICATION OF MECHANISM FOR TWO-POSITION ELECTRO-PNEUMATIC HIGH SIGNALS GIVING INDICATION IN LOWER QUADRANT

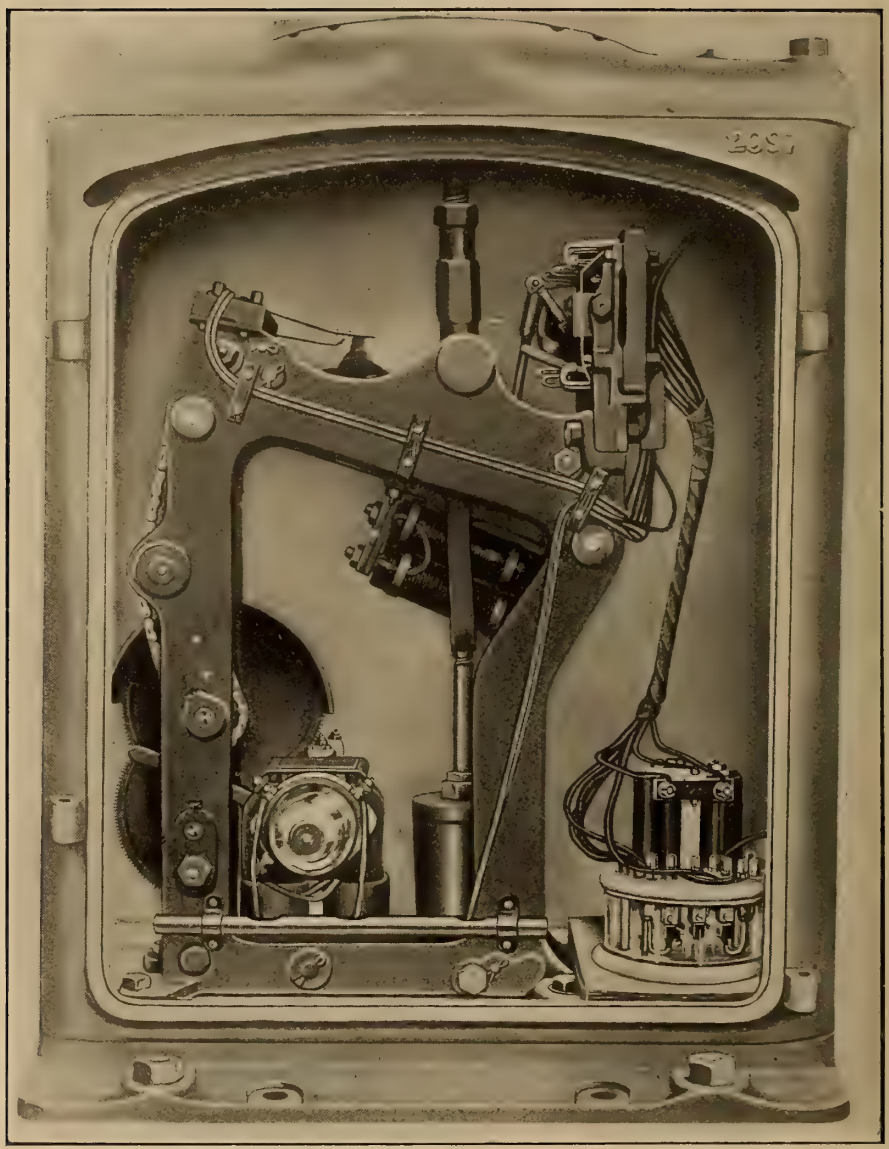


FIG. 13.—THREE-POSITION ELECTRIC SEMAPHORE SIGNAL MECHANISM

signal for all conditions is admitted generally to be the electric-motor type, of which there are several styles. Two of these (Figs. 15 and 16) are more largely used than any others, there being to-day over 34,696 in active service, the first having been installed in 1898.

In these signals a 10-volt electric motor, the current for which is furnished by either primary or storage batteries located adjacent to it, drives one or more Morse chains through a train of gears. The chains are fitted with trunnions which engage with the ends of levers known as "slot arms" connected to the semaphores by vertical rods extending upwards through the hollow mast.

The slot arm is carried upwards

by the chains and deposited on hooks at the intermediate position for "caution" and the upper position for "proceed," the semaphore arm to which it is attached moving correspondingly. Through a system of levers and electro-magnets the slot arm can, at any time, be disengaged from either the trunnions, if in motion, or from the hooks, if at rest, and returns, with its corresponding semaphore, to the "caution" or "stop" position by gravity. A buffer is attached to the arm to absorb the blow of the sig-

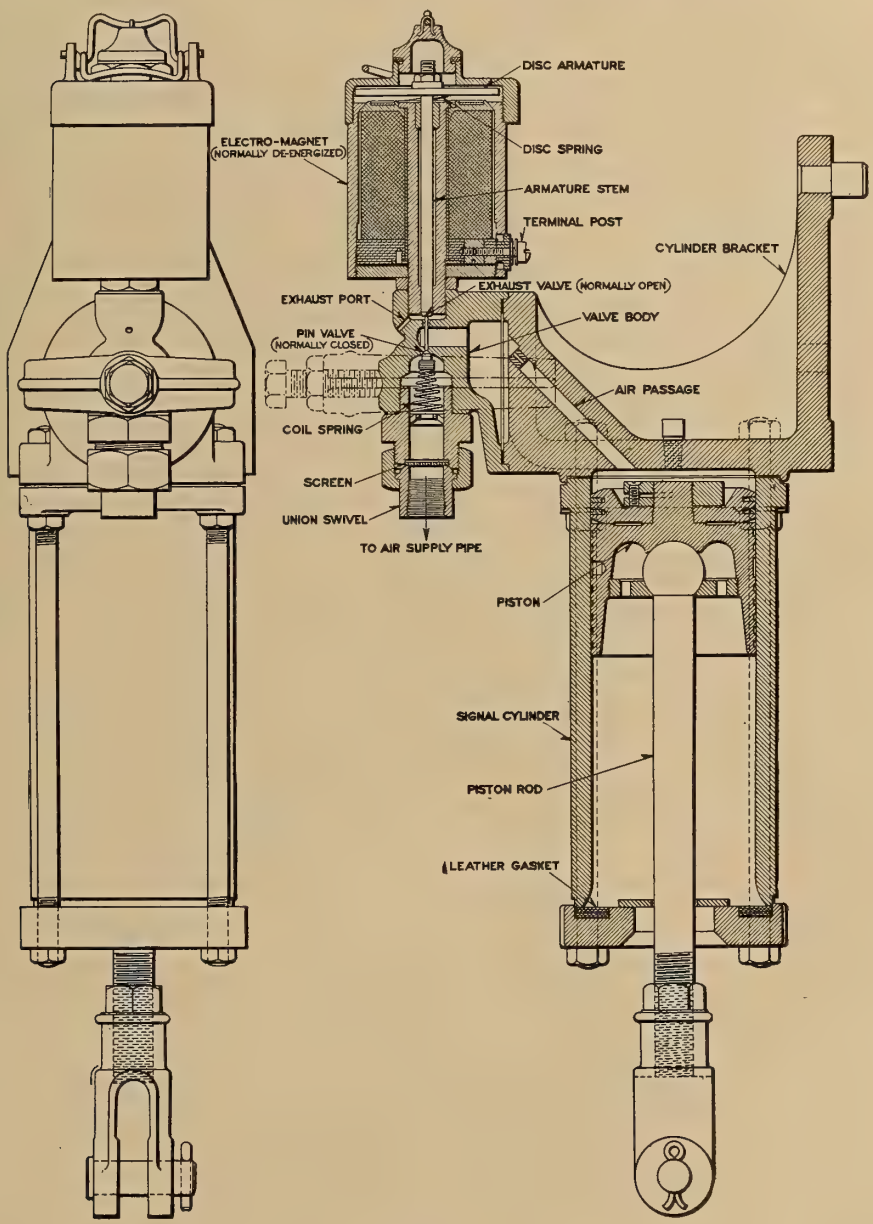


FIG. 14.—DIAGRAM OF PARTS OF ELECTRO-PNEUMATIC SIGNAL APPARATUS

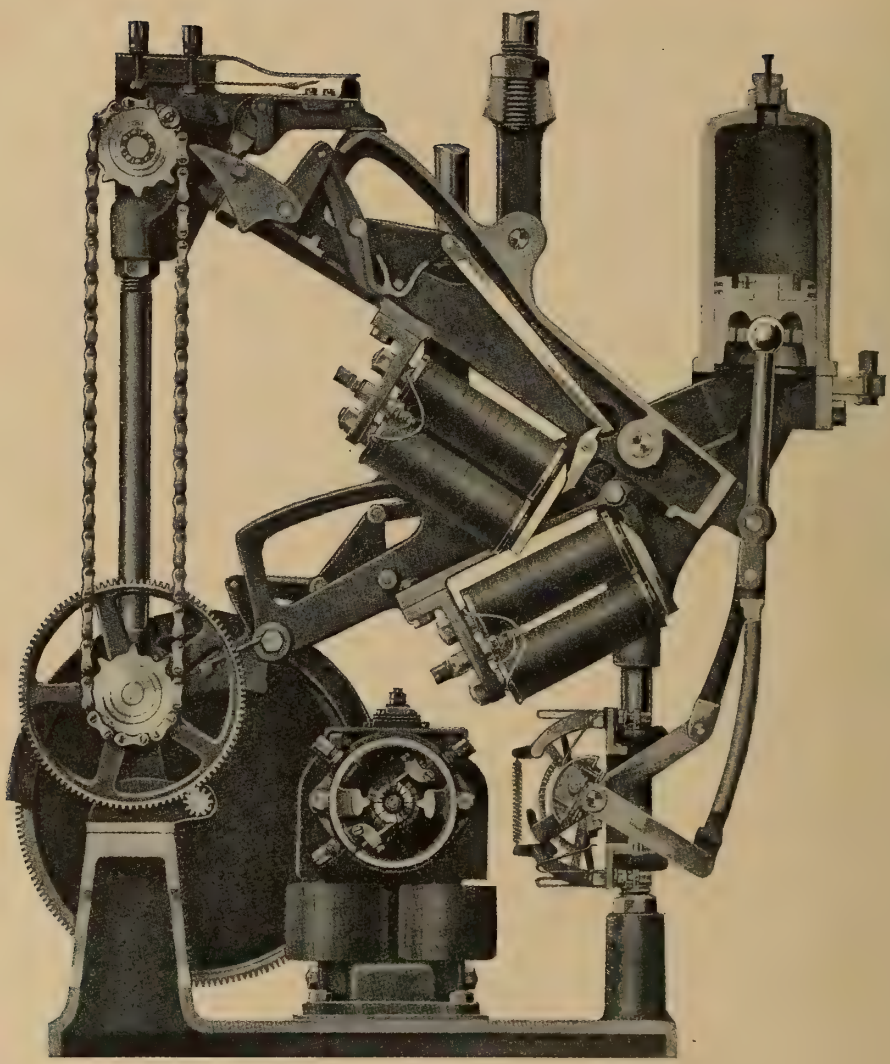


FIG. 15.—SECTIONAL VIEW OF THE MECHANISM OF THE SEMAPHORE MADE BY UNION SWITCH & SIGNAL CO., SWISSVALE, PA.

nal returning to either position. A feature of this signal is that but one motor and gearing are required for any number of arms.

As the electrification of railroads developed, the demand arose for a continuous track circuit which would operate without interference from the propulsion current returning along the track rails. This demand was first met by a system installed on the Boston Elevated in 1900, wherein one rail was reserved for block purposes entirely, the other being common to both the block and propulsion return. The relays were operated on a voltage considerably higher than the maximum drop of the propulsion return in the longest block.

The next advance was to employ alternating current for the operation of the track circuit in conjunction with a relay (Fig. 17) irresponsive to direct current. In one system a rail is given up exclusively for block

purposes, where engineering conditions make this desirable.

In another system an appliance known as an "inductive bond" (Fig. 18) is installed at the end of each block or sub-section, by means of which both rails can be used for the alternating current of the track circuit and the return of either the direct or alternating propulsion current. The inductive bonds provide metallic conductors of ample capacity to carry the return propulsion current around the insulated joints, but set up electrical impedance to the passage through these con-

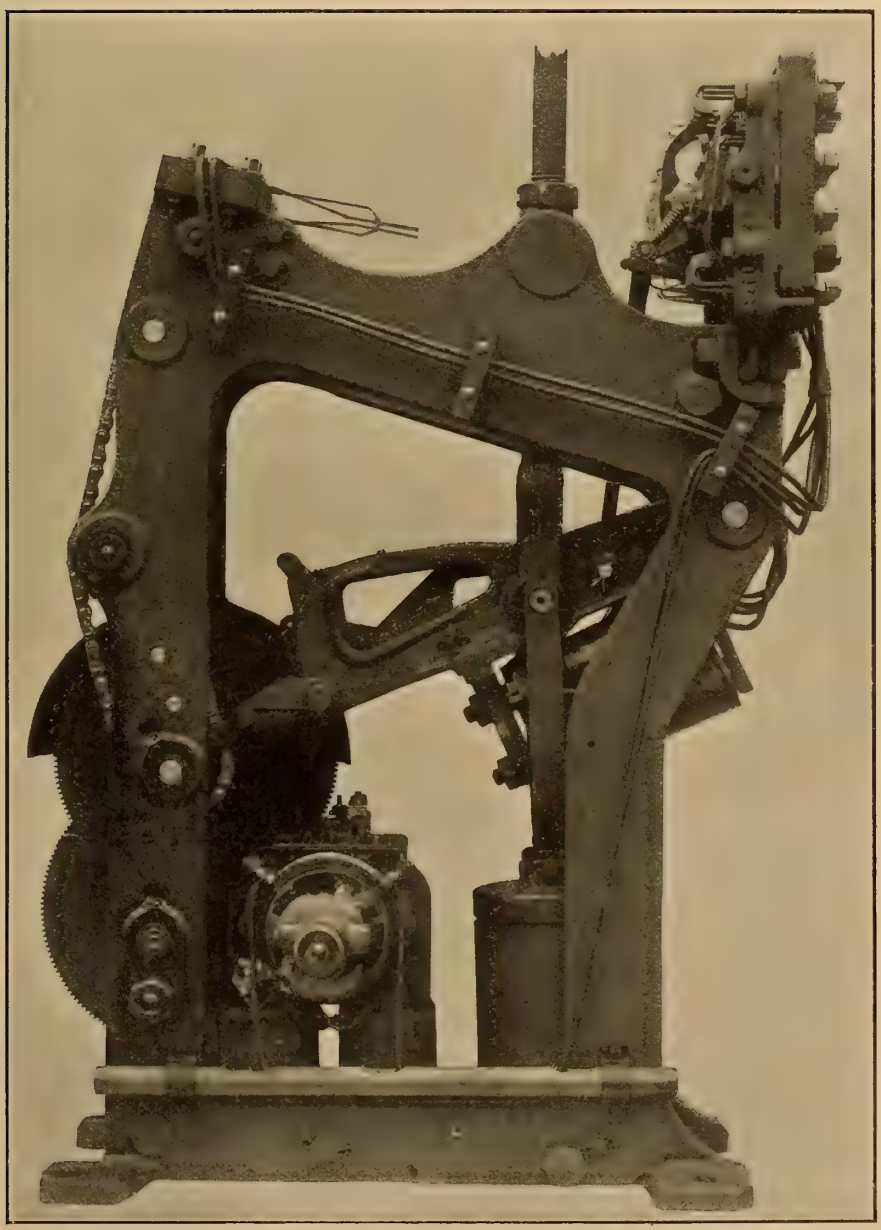


FIG. 16.—UNION ELECTRIC SEMAPHORE MECHANISM

ductors of the alternating current for operating the track relays.

In electric railways employing 25-cycle, single-phase, alternating current for propulsion, "frequency relays" are employed, which respond only to alternating currents of a given frequency, usually 60 cycles, and, consequently, will not be affected by the propulsion current of a different frequency.

Alternating current is being used to some extent in recent installations for the operation of signal motors, electric locks and other appliances forming parts of automatic block systems, as well as for lighting the signals. In several installations where this practice has been followed the results have been eminently satisfactory.

The last refinement in automatic signaling is the "train stop" (Fig. 19) used on several electric railroads. By means of this instrument the air brakes of a train are automatically applied in the event of its passing a signal in the "stop" position. Train stops, so far, have not been applied to any extent on surface railroads, and for many reasons their adoption by such railroads is problematical.

"Cab signals," or visual signals located in the cab of the locomotive, have furnished a fertile field for inventors; but, so far, have met with little favor. The present general

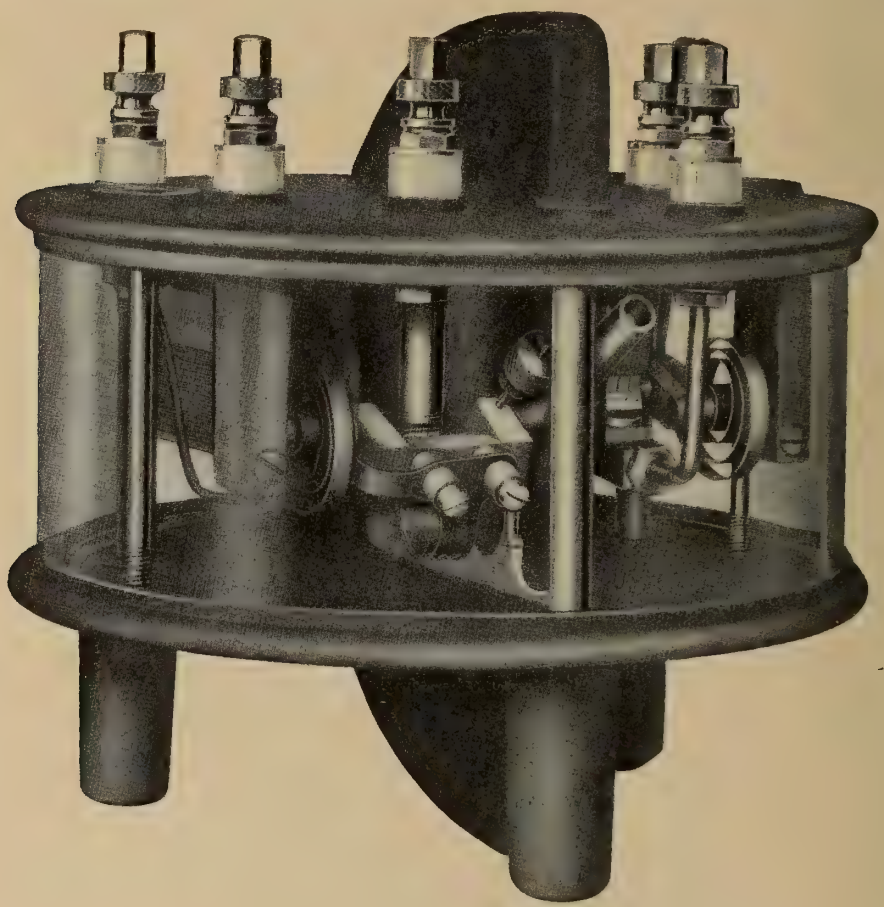


FIG. 17.—ALTERNATING-CURRENT RELAY

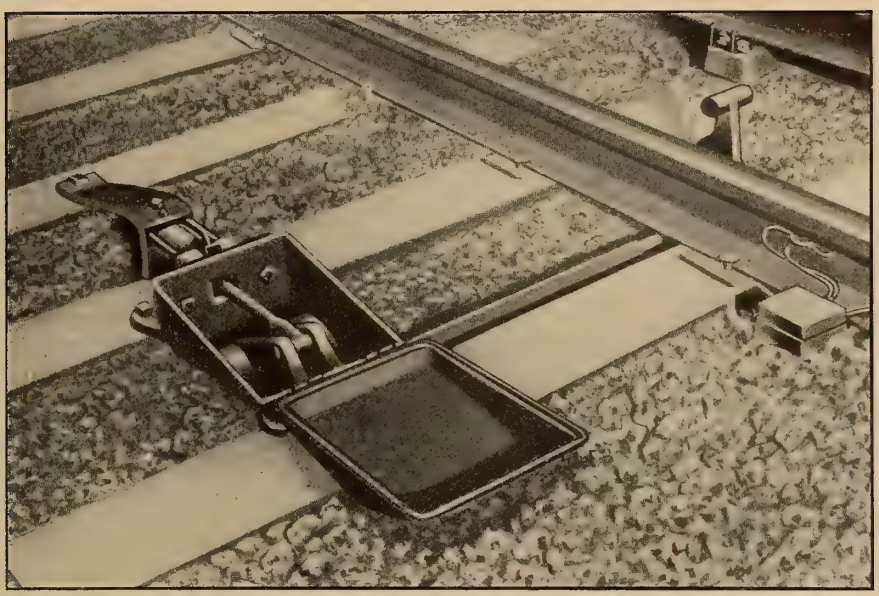


FIG. 19.—AUTOMATIC TRAIN STOP

feeling among railroad officers seems to be that, as an engineman must of necessity observe the tracks as closely as possible all the time his train is in motion, it is not desirable to divert his attention from them by requiring him to observe visual signals located in the cab.

The following table, compiled from a list published in the *Railroad Gazette,* of January 11, 1901, and from the report of the Interstate Commerce Commission of January 1, 1909, shows the growth of block signaling in the past eight years:

MANUAL AND CONTROLLED MANUAL SYSTEMS.

Date.	Miles of Road Protected. Single Track.	Two, Three and Four Track.	Total.
January, 1909	38,407.4	8,950.7	47,358.1
January, 1901	18,144.0	5,868.9	24,012.9
Total increase	20,263.4	3,081.8	23,345.2

AUTOMATIC SYSTEM.

Date.	Miles of Road Protected. Single Track.	Two, Three and Four Track.	Total.
January, 1909	5,126.0	7,064.6	12,190.6
January, 1901	405.5	1,889.2	2,294.7
Total increase	4,720.5	5,175.4	9,895.9

From this table it is apparent that while the miles of railroad protected by all manual systems have not quite doubled in eight years, the total mileage protected by automatic signals has more than quadrupled. The most significant fact, however, is that the amount of single track on which automatic signals are installed has increased almost twelve times.

INTERLOCKING

The object of an interlocking plant is to provide for the safe passage of trains over routes that may conflict with other routes, such as two tracks crossing each other at grade, or the junction of two or more tracks, or for a railroad crossing a navigable body of water by means of a drawbridge.

An interlocking plant comprises an interlocking machine contained in a centrally located cabin, of such height as to afford a clear view of the tracks, a sufficient number of signals to control trains passing over the various routes, the switches, and the connections for operating and locking the signals and switches from the machine.

An interlocking machine consists of an iron frame supporting a num-

ber of levers arranged side by side and to which a "locking table" (Fig. 20) is attached. This latter comprises a series of grooves crossed at right angles by a second series, all of which contain rectangular steel bars free to slide endways in their respective grooves. To these bars steel blocks with beveled surfaces (known as "locking dogs") are attached for engaging with corresponding surfaces on the bars crossing them at right angles, each of which is connected by a suitable mechanism to a certain lever in the machine. The preliminary movement of a lever or its latch slides its locking bar horizontally, and by the particular arrangement of the "dogs" on that bar motion is transmitted to one or more of the bars or crosslocks lying at right angles to it, which, in turn, locks or releases the locking bars of other levers, and thereby prevents or permits their manipulation with relation to the lever first moved. By this arrangement the levers are so interlocked that it is mechanically impossible to give conflicting signals, or to give any signal, until the switches are properly set and locked.

The first interlockings, installed in England in 1847 and in the United States in 1874, were of the "me-

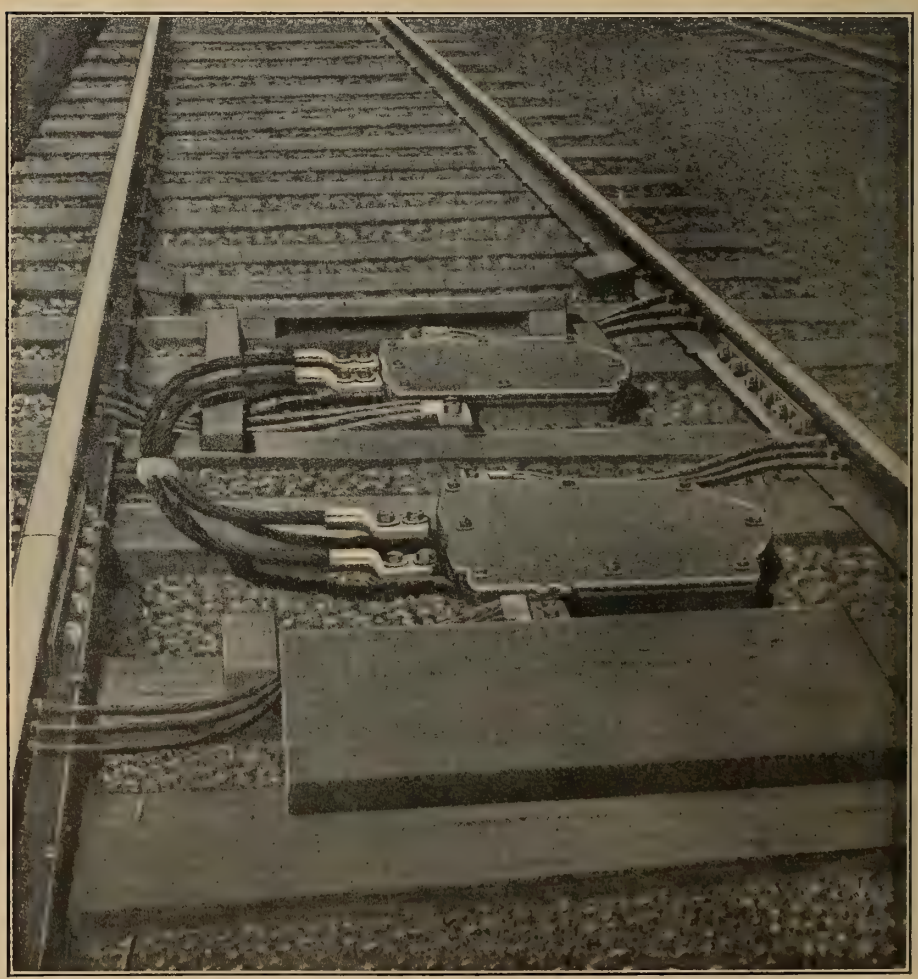


FIG. 18.—INDUCTIVE BONDS IN PLACE IN TRACK

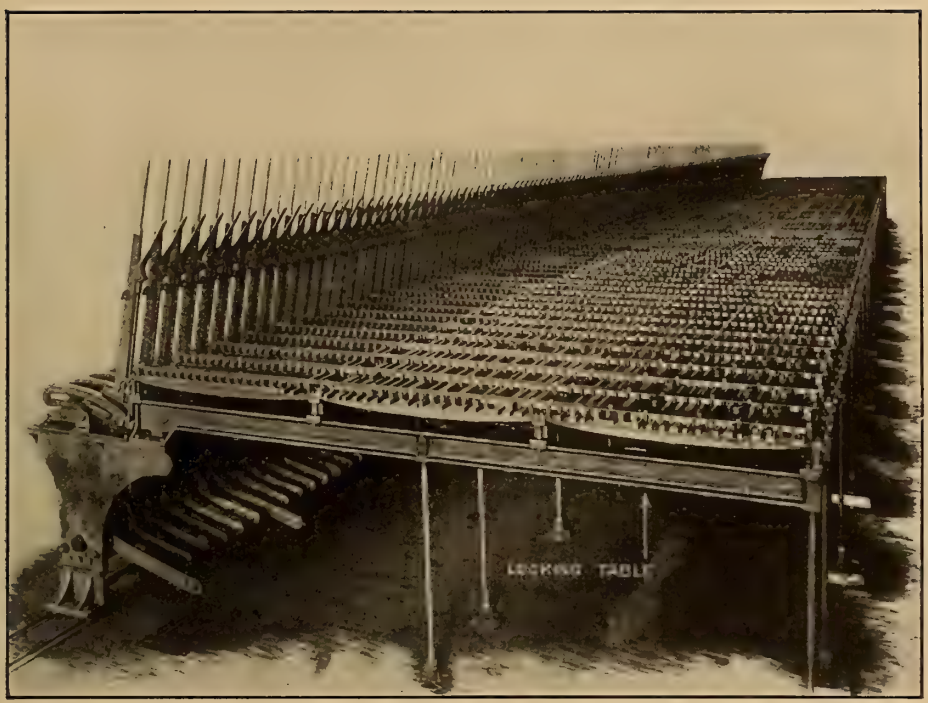


FIG. 20.—MECHANICAL INTERLOCKING MACHINE

FIG. 21.—MECHANICAL CONNECTIONS FROM LEADING MACHINE TO THE VARIOUS FUNCTIONS, SHOWING THE SPACING OF ANTI-FRICTION PIPE CARRIERS

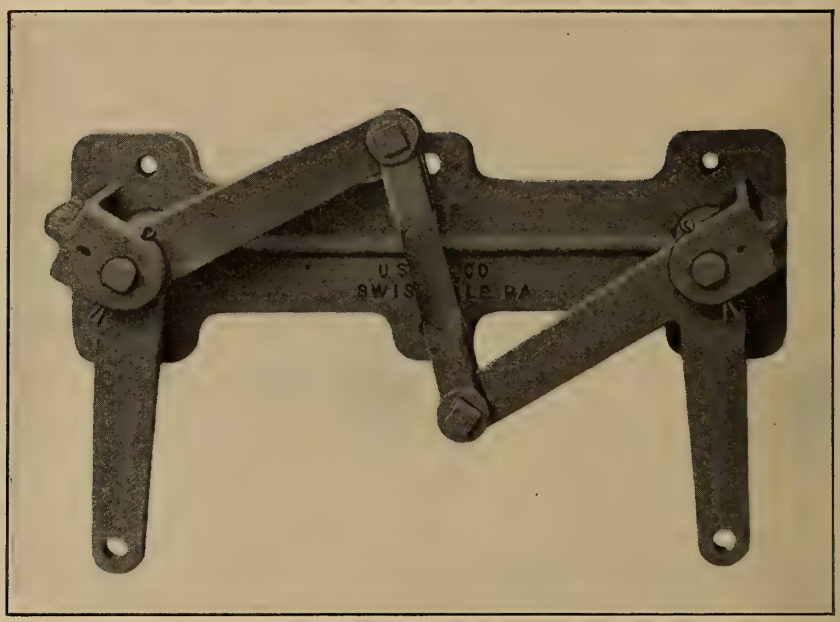


FIG. 22.—LAZY JACK COMPENSATOR

chanical" type, in which the switches, signals and locks are manually operated by levers about 6 feet long through mechanical connections. By far the greatest number of plants in use to-day are of this design, on account of their comparatively low cost of erection and maintenance.

The mechanical connections leading from the machine to the various functions it works now generally consist of 1-inch pipe carried in anti-friction carriers (Fig. 21) placed 7 feet apart, though on the older plants two lines of steel wire are used for the operation of signals. The expansion and contraction of pipe lines are taken care of by compensators (Fig. 22), one of which is placed in every 700 feet of the line. Turns are made by bell cranks (Fig. 23) or by deflecting stands (Fig. 24). Foundations of concrete or cast iron are used to support these appliances, as well as the signal masts, which are constructed of pipe set in cast-iron or steel sockets. The whole tendency of modern interlocking construction is towards permanency, irrespective of first cost, the use of wood being almost entirely eliminated.

Electricity is now largely used in mechanical interlocking for the operation of distant signals, usually located on high-speed tracks one-half mile or over from the home signal they repeat, for the announcement of approaching trains, for repeating the indication of signals invisible from

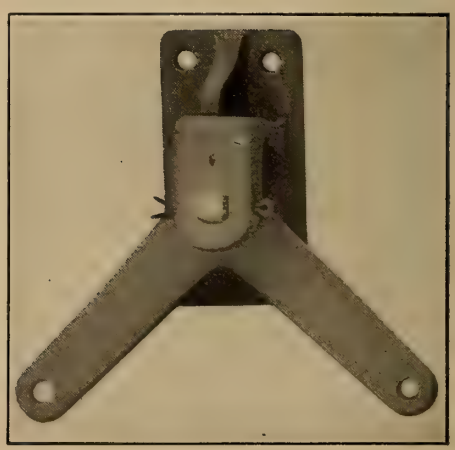


FIG. 23.—BELL CRANK

the cabin, for locking certain routes when occupied by trains, and for many other purposes.

An electro-mechanical system has recently been devised in which, while the switches are manually actuated through mechanical levers and connections, they are locked and released electrically, and all signals are electrically operated. The operation of switches and signals through mechanical connections is usually limited to distances of 800 feet for a switch and 2,000 feet for a signal, while even these lengths of connections are somewhat difficult to operate and keep in adjustment. Furthermore, on large installations the cabin and pipe lines take up a good deal of valuable space usually difficult to secure. Lastly, to operate a busy plant expeditiously at a large terminal or junction requires the services of several signalmen at once.

To overcome these difficulties the power interlocking system was devised in 1876, and is now in use on many railroads where the conditions are such as to require it.

Although interlockings are and have been worked by hydraulic, hydro-pneumatic, pneumatic, electro-pneumatic and electric power, the last two are the only ones now considered as complying with modern requirements. The electro-pneumatic system, as its name implies, is designed to operate switches, signals and other functions by compressed air admitted to and released from cylinders through electrically-controlled valves, the operating levers being locked and released electrically by the positions of their respective functions.

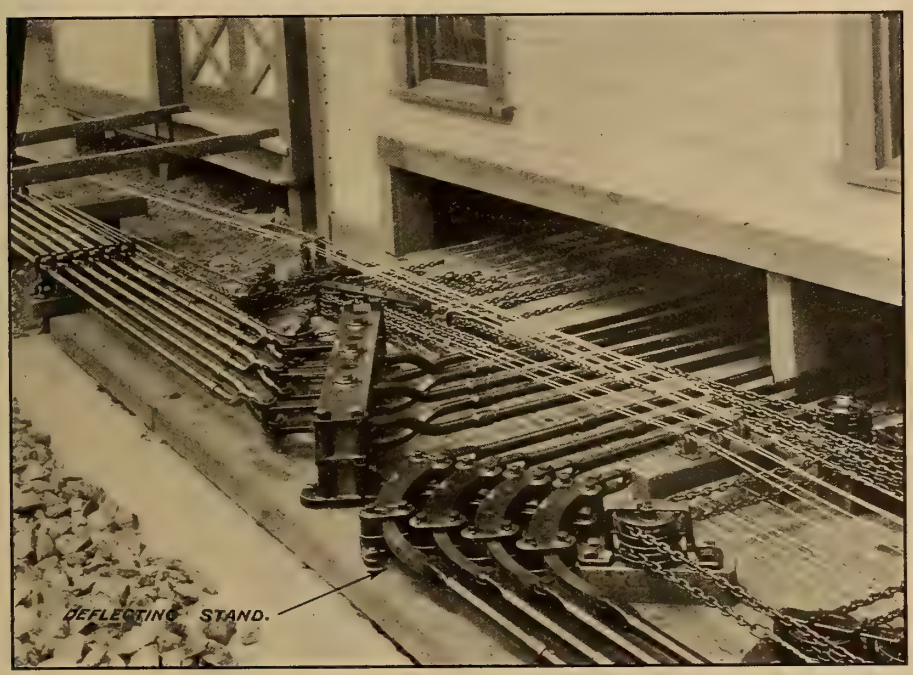


FIG. 24.—LEADOUT FROM MECHANICAL INTERLOCKING MACHINE

Fig. 25 shows a modern electro-pneumatic machine with and without its case. The levers are arranged in one row and point alternately up and down, the former being switch and the latter signal levers, though both may be used for either purpose. A switch lever normally points to the left and can be moved through an

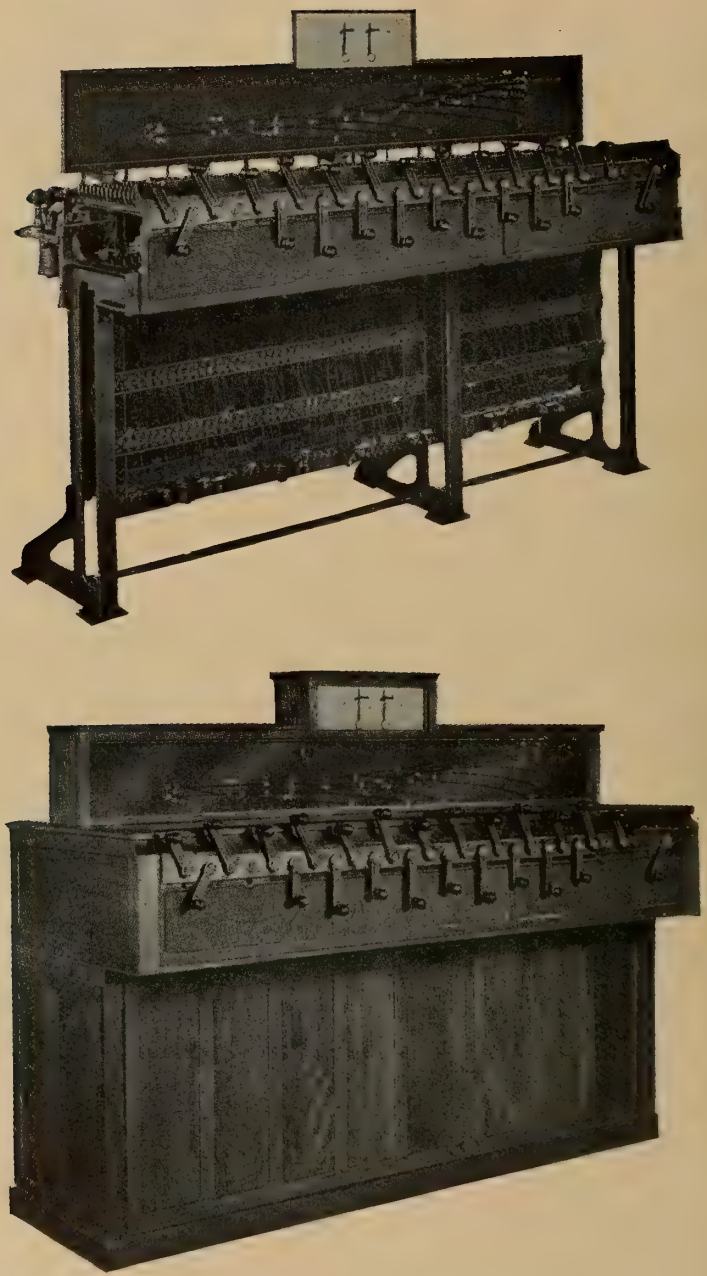


FIG. 25.—ELECTRO-PNEUMATIC INTERLOCKING MACHINE OF THE VERTICAL ROLLER TYPE

arc of 60 degrees to the right, in traversing which it first causes the unlocking of a switch, then its reversal, and finally its re-locking. A signal lever is capable of three distinct positions, and stands vertical when normal. It is moved 30 degrees to the left to clear a signal for a train proceeding from right to left and the same amount to the right for a train going in the opposite direction. Each lever is rigidly secured

to a horizontal shaft which operates the mechanical locking, and through bevel gears transmits motion to a vertical roller, by means of which the electrical controlling circuits are opened and closed. Quadrants are attached to the horizontal lever shaft, engaging with electrically-operated latches (known as indication latches), which lock and release the lever by means of circuit controllers on the switch or signal it operates. To move a switch from the normal to reverse position, the switch lever is turned 45 degrees to the right, where a projection on one of the quadrants strikes against the indication latch and prevents further movement. The signal indication circuit and releases the lever, which can then be returned to the vertical or normal position.

The object of the indication control is to insure that each switch and signal shall follow the movement of its respective lever, or failing to do so through any cause, that no unsafe conditions shall result.

A switch and lock movement is shown in Fig. 26, consisting of a double-acting cylinder, an electric valve for controlling it, and the movement itself, all secured to a base plate and bolted to the ties. In one complete movement of the piston the switch is first unlocked, then moved, and finally re-locked in the opposite

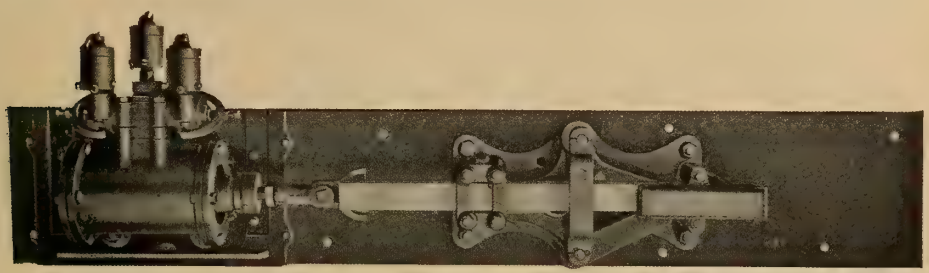


FIG. 26.—ELECTRO-PNEUMATIC SWITCH AND LOCK MOVEMENT

air pressure being reversed in the switch cylinder through this movement and the switch having moved to and been locked in the reverse position, the indication circuit is closed, which releases the indication latch, when the lever can be moved the remaining 15 degrees to the right, thereby releasing the mechanical locking. To clear a signal, the lever is moved the full 30 degrees to the right or left, and in doing so admits air to the signal cylinder, thereby clearing the signal. To return the signal to the "stop" position, the lever is moved about 25 degrees towards the vertical, at which point it is stopped by the indication latch.

This movement opens the signal-controlling circuit and releases the air from the signal cylinder, permitting the signal to return to "stop" by gravity. In so doing it closes the position. The switch and lock movement is connected to a bar 50 feet long (or several bars aggregating 50 feet) lying alongside the rail in brackets, which is raised above the rail each time the switch operates. When a train stands on or moves over the rail, or rails, to which the bar is attached, the latter will engage with the treads of the wheels and prevent the switch being moved. This device is known as the "detector bar," and is also used on mechanical plants.

In recent installations track circuits operating electric locks on the machine levers are taking the place of the mechanical bars.

Most of the great railroad termini in the United States are equipped with the electro-pneumatic interlocking system, among which may be mentioned St. Louis, Washington,

Boston, Jersey City, Long Island, Philadelphia, Pittsburg, Kansas City, Oakland, California; etc. It is also being installed at the new Pennsylvania terminal in New York. It is very largely used on urban railroads, such as the New York. Philadelphia and Boston Subways, and the elevated railroads of Boston and Chicago, where frequent and heavy traffic is handled. There are also many installations of this system at junction points and crossings of steam railroads.

The first successful electric interlocking was installed in 1891, since when it has been rapidly growing in favour. Several makes of electric interlocking machine are in successful operation, one of which is shown in Fig. 27. In this machine the "lever" resembles the stock of a pistol, and in its normal position stands at an upward angle to the horizontal. To operate this lever it is first pulled towards the leverman and then moved radially downward against a stop. On the indication being received, the lever is automatically moved inward by a compression spring, the locking being released by this last movement. The indication circuits for compelling the function operated to follow the movement of its lever are arranged on the same general principles as those in the electro-pneumatic sys-

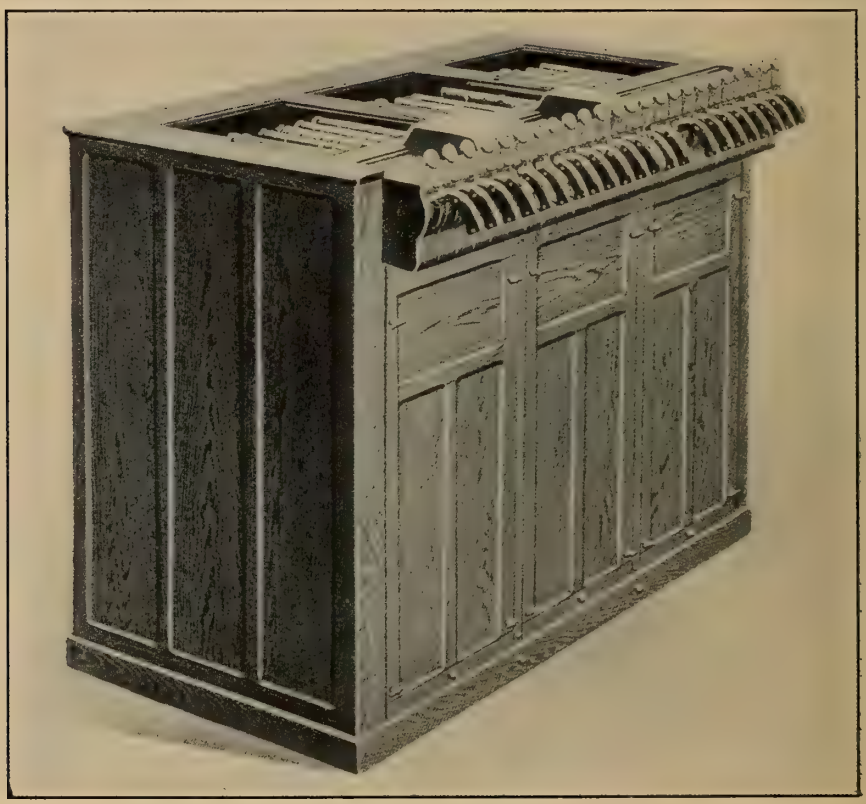


FIG. 27.—ELECTRIC INTERLOCKING MACHINE

The electric interlocking system employs 110-volt, direct-current motors for the operation of switches and high signals and solenoid magnets for low or dwarf signals, the power being furnished by a battery of 55 cells of storage battery located in the cabin.

tem, except that in the electric systems the current for their operation is usually generated by the motor acting as a generator.

In all types of modern interlockings the automatic track circuit is largely used for the semi-automatic control of signals, for preventing the movement of switches when trains are standing on or approaching them, for announcing the approach of trains, and for many other purposes.

In several recent interlockings working models of the tracks are installed immediately in front of the leverman, which automatically indicate the presence of trains on each of the sections into which the tracks are divided. By means of these the leverman can operate his plant without actually seeing either the tracks or the trains.

POWER RAILWAY SIGNALING

CURRENT BRITISH PRACTICE

By J. F. Gairns

ALTHOUGH the term "power signaling" is employed generically to describe all applications of electric power or fluid pressure for the operation of railway signaling apparatus, the subject is, in fact, anything but unitary. It may be that only the signals are operated by power, or the points only. Or it may be that the operation of both signals and points is effected and controlled by power, but that their interlocking is mechanical. In other cases, while the operative features are the same, as with a purely mechanical installation, the motive agent and control are entirely of a power character. In the case of automatic or semi-automatic installations still further features are involved, and in other cases provision is made for alternative automatic, semi-automatic or non-automatic operation and control, or for combined automatic and non-automatic working.

It will be seen, therefore, that the subject is a voluminous one, especially as more than a dozen systems, with their associated apparatus, are more or less extended in use, and many of these have several modifications which time and development have made between earlier and later plants. To a great extent, however, this article will have to take the form of a general review of practice, and it will be possible to go into elaborate detail as to the devices employed, while the circuits and connections, and many of the actual mechanisms employed, will have to be referred to in very general terms. As far as possible, however, the author has attempted to provide an adequate and reasonably exhaustive review of practice with reference to the principal systems and apparatus now in regular use.

Before dealing with actual systems and apparatus a good deal of ground will be cleared if certain aspects of the subject are first dealt with in more or less general terms.

The advantages of power signaling in its various aspects may be briefly summarized as follows:

(*a*) The use of power for the operation of railway points and for signals relieves the signalmen of physical strain.

(*b*) It enables the complicated, awkward and expensive wiring and rodding characteristic of a large, manually-operated station or yard to be dispensed with, as small pipes or electric wires, disposed in convenient fashion and adequately protected, are used instead.

(*c*) The signal box mechanism can be made very compact, as the levers are small and close together, and the locking frame reduced in dimensions, whether it be of mechanical character, in which case ordinary practice is followed in miniature, or entirely electric or pneumatic.

(*d*) A comparatively small cabin can be made to replace several manual cabins in different places, and the control is, therefore, concentrated. Moreover, a small cabin can be placed in the most convenient position, whereas a large manual cabin takes up a lot of room, and is frequently more or less awkwardly located.

(*e*) The signal staff can be considerably reduced.

(*f*) The safeguards and checks can be made much more elaborate

than is usually desirable or practicable with manual boxes, and the trains can be made to control partly their own movements, to return signals to danger independently of the signalmen, and other means can be used to facilitate traffic operation and to lessen the work of the signalmen.

(*g*) Selector mechanisms, by which one mechanism can be made to do duty for several distinct purposes, can frequently be employed without the complications that a similar procedure with manual signaling usually entails.

(*h*) By automatic signaling the services of signalmen can be dispensed with entirely, except at junctions or at places where points have to be operated regularly; and in cases where points require to be only occasionally operated, the services of a signalman are necessary only at the time of operation.

(*i*) In alternative manual or automatic schemes, signal-boxes can be switched out when traffic permits of automatic working being maintained, whereas according to the ordinary methods of switching out a signal cabin the effect is merely to lengthen a section, and the box in question and its through signals, which all have to be lowered and to remain so, become, to all intents and purposes, non-existent.

(*j*) "Distant" signals, when located at a considerable distance from the signals which they repeat, can be very conveniently operated by power, and in some respects may operate automatically, even when they correspond to signals which are not power-operated. Moreover, distance and obstacles need no restrictions as regards the location of a "distant" signal, whereas with manual operation mechanical limitations have to be considered.

In the United States a considerable number of automatic signals have been installed in order to break up long sections which would otherwise not be signaled intermediately at all, and such signals, either wholly or

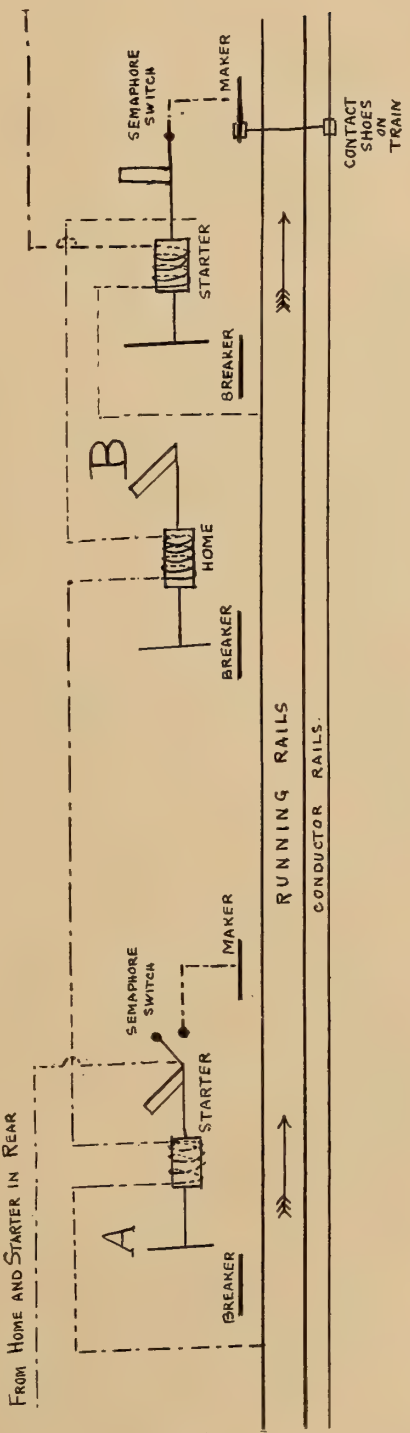


FIG. 1.—TRACK AND SIGNAL CIRCUITS AS FITTED FOR AUTOMATIC SIGNALING ON THE LIVERPOOL OVERHEAD RAILWAY

partially automatic, have been installed to some extent in Great Britain and other countries.

As regards non-automatic power signaling, there is little that requires to be said at this juncture, because, although signals, points, interlocking, and so on, are operated and controlled by the agency of power, the main features, so far as traffic control is concerned, are the same, or nearly so, as with manual and mechanical operation and control. Consequently, interest mainly centres in the actual apparatus employed. In the case of automatic signaling, however, the system of operation and the various methods of signaling, apart from the apparatus used, require brief consideration before practice is dealt with in detail.

With automatic signaling, point mechanisms, interlocking frames, and so on, are not involved, except as far as they are necessarily concerned, owing to the fact that a signal cabin (or a lock-up interlocking frame not ordinarily employed) is inserted between automatic sections, or has to be installed for the purpose of controlling junction working. In many cases, particularly in the United States in the remoter districts, the points are operated by ordinary switch levers alongside them, there being no actual relation between the signal apparatus and the point mechanisms, except that the track circuits are so arranged that unless the points are correctly set to correspond with the signal indications, the track circuits which control the signals are rendered inoperative, to give a "line-clear" indication.

In essence, automatic signaling may be said to consist in the provision of means whereby, as a train enters one section, it automatically causes the signals behind it to go to "danger" and releases those controlling the entrance of the section that it has just left. This involves that the normal position of the signals shall be at 'line clear," and this was one of the greatest hindrances to the adoption of automatic signaling in Great Britain. When, however, it is considered that, whereas in ordinary signaling the signals inform a driver that the road is prepared for him, in automatic signaling the indication is merely that there is nothing in the way in the section before him, the objection against the "normal clear" system is largely removed, and this is becoming more and more realized. As a matter of fact, however, apparatus has been employed whereby, although a signal is released as the section in front is cleared, it is not actually lowered until a train is approaching; but it has been shown that this introduces complications that are not really necessary and the objections to the "normal clear" system largely vanish, so long as it is ensured that if anything goes wrong a signal shall take the "danger" position. This means that the normal condition shall be that the signal is positively held off and only goes to danger when such holding means are removed, as by the short circuiting of the control current by a train in the section to be protected, or the opening of the control circuit by misplaced points, or from other cause. It is generally found that the cost of a maintained holding-off current is not great, even where trains are not frequent; but in many cases means are fitted whereby another holding off is provided, and the controlling electric circuits merely cause the initial operation of moving a signal to the "line clear" position, or of releasing it to allow it to go to "danger."

In its simplest form an automatic signaling apparatus comprises electric contacts at the beginning and end of a section, which are made or broken by the passage of a train; and some installations do little more than provide for this, though, as a rule, the actual signal control is effected through relays, the voltage of the relay currents being small. Fig. 1 shows in diagrammatic form the arrangement employed on the straight-

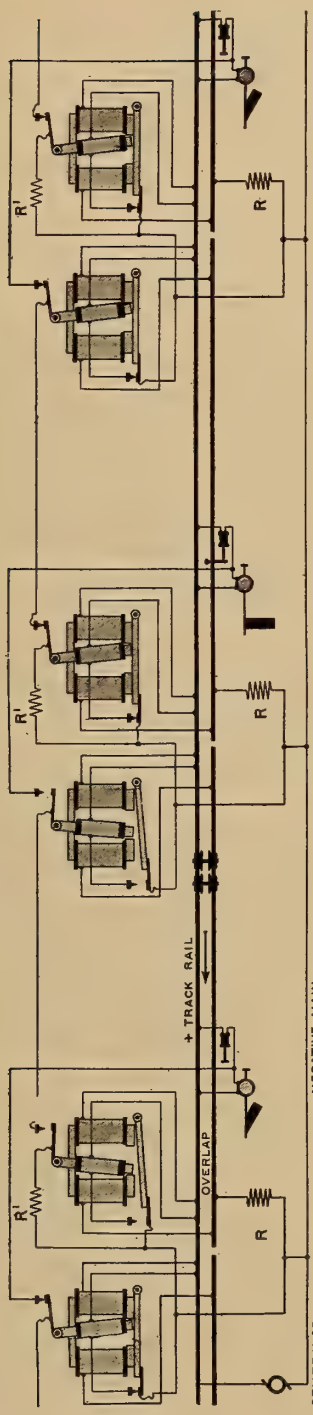


FIG. 2.—DIAGRAM OF WESTINGHOUSE AUTOMATIC SYSTEM FOR ELECTRIC RAILWAY

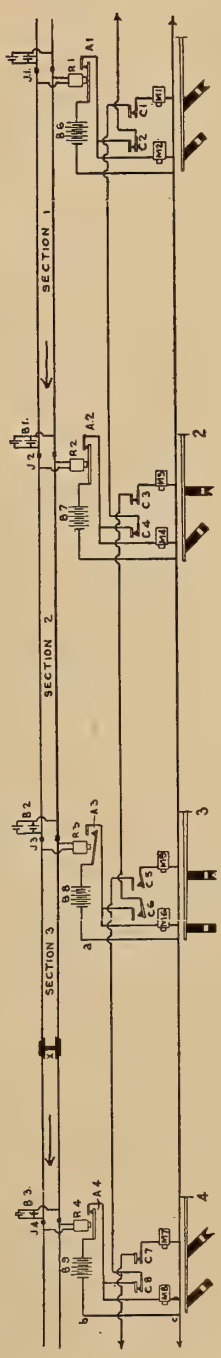


FIG. 3.—AUTOMATIC SYSTEM OF BRITISH PNEUMATIC SIGNAL COMPANY, LTD., WESTMINSTER, S. W.

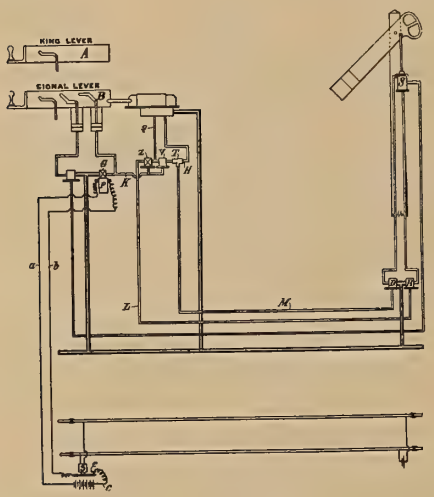


FIG. 4.—AUTOMATIC STATION SIGNAL WORKING. BRITISH PNEUMATIC SIGNAL COMPANY, LTD., WESTMINSTER, S. W.

forward sections of the Liverpool Overhead Railway. This railway provided one of the first instances of the use of automatic signaling in Great Britain. These signals were operated on the Timmis system, and the current for working the signals was obtained from accumulators. The use of accumulators being troublesome and expensive, experiments were made by Mr. S. B. Cottrell about two years ago, then manager and engineer, with a view to working the signals with current from the conductor rail. The original system has been fairly frequently described; but by the courtesy of Mr. S. J. Neachell, the present manager and engineer, we are enabled to illustrate and describe the apparatus now installed.

In this system the signals are lowered electrically, and are held off and put to danger mechanically, hence the consumption of electric energy is very small, the current flowing only during the short interval occupied by the train completing the electrical circuit. Each train is fitted with four collector shoes, one on each side at both ends of the train. These shoes are connected by cables with one another and with the positive terminals in the two controllers, so that if any one or more of the shoes make contact with the conductor rail all the shoes are alive. The conductor rails, as a rule, are laid in the 6-foot way; the two shoes on the right-hand side of the train are, therefore, in contact with the conductor or positive rail, whilst the two shoes on the left-hand side of the train hang freely in the air. It is these "idle" shoes which are employed in the working of the signals.

On leaving station *A* the train passes the starter signal, and in so doing the "idle" shoe strikes the breaker-bar *B*, which is insulated electrically from the structure and from the signal, but is connected mechanically with a trip rod leading up the semaphore arm in the "off" position. This pawl is then released and the semaphore arm goes to "danger" by dead weight, the spectacle casting being considerably heavier than the signal arm.

Each starter signal is fitted with a semaphore switch, placed in the electric circuit leading from the home and starter signals in the rear to the

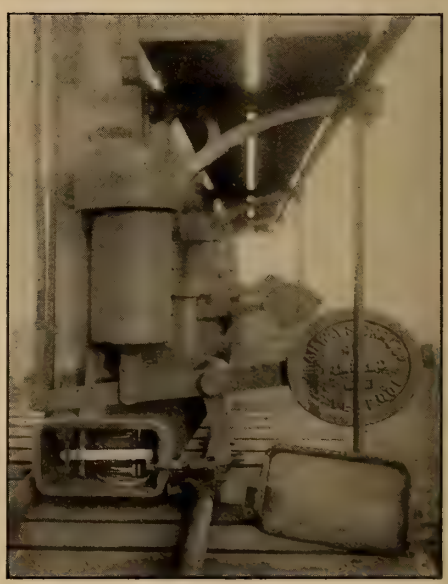


FIG. 6.—SIGNAL MOTOR, "CREWE" ELECTRIC SYSTEM, RAILWAY SIGNAL COMPANY, LTD.

maker bar *M* in advance. This semaphore switch is open when the signal to which it is fitted is in the "off" position, but is automatically closed on the arm going to "danger." The train having put the starter to "danger" is now protected to the rear, and proceeds to the maker bar *M*.

In more elaborate installations, however, track circuits are the rule, and a good deal of the satisfaction given by automatic signaling with heavy traffic is due to the efficiency and reliability of the track circuits and relays. The general principle is that one running rail constitutes a continuous positive conductor for the control current, the joints being bonded and the rails insulated, while the other rail is divided into sections insulated from one another, although the intervening joints must be bonded. The entrance of a train into a section provides a short circuit, which causes the de-energizing of a relay circuit, this causing the breakage of the signal circuit and allowing the signal to move to "danger" by gravity. This system has been extensively developed by the Westinghouse firms, and in Fig. 2 an instructive diagram prepared by them is reproduced.

The actual signal operating are controlled through relays involved in the track circuits. When a section of track has no train on it the relay coils are excited, owing to the potential difference between the (positive) continuous and sectional conductors constituted by the running rails, and a circuit is closed in the swinging coil, which is then attracted to one of the poles of the relay, and by swinging over completes the signal circuit concerned. For each block there are two relays, one at each end, and each

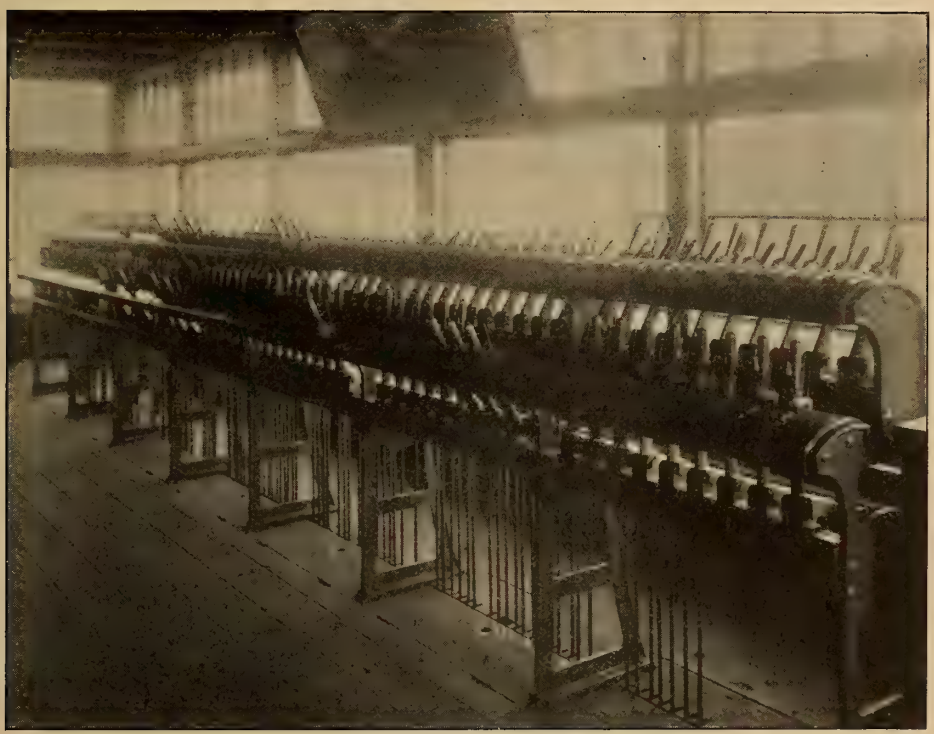


FIG. 5.—INTERIOR OF SEVERAS' JUNCTION CABIN, "CREWE" SYSTEM, RAILWAY SIGNAL COMPANY, LTD., FAZAKERLY, LIVERPOOL

closes a contact in the same signal circuit whereby the signal motor is allowed to act and move the signal to the "line clear" indication. As a train enters a section, the relays are short circuited through the axles, and, being de-energized, the circuit through the swinging coil is broken, causing the signal circuit to be broken at both contacts, with the result that the signal motor is released and the signal by gravity returns to the "danger" position.

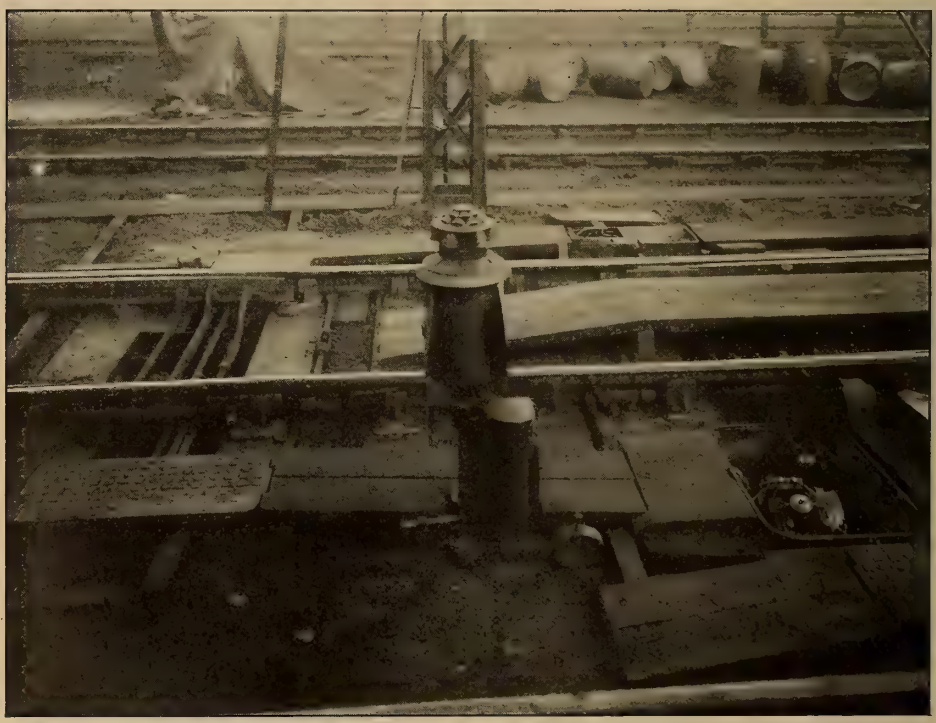


FIG. 7.—POINT MOTOR AND DETECTOR BOX, AND A DISC SIGNAL. RAILWAY SIGNAL COMPANY, LTD., FAZAKERLY, LIVERPOOL

As a rule, the sections of an automatically-signaled road are made as short as possible, for the unit of traffic movement must be the time occupied by a train in traversing the longest section. This means that the headway is very short, and some provision has to be made to obviate risks due to the fallibility of motormen, especially as otherwise there would be no latitude to provide for overrunning a signal. Of course, one of the strictest rules of signaling is that a signal at "danger" must never be passed; but when drivers are passing signals every half minute or even less for hours every day and day after day, it is too much to expect that they should never be caught napping. In some respects the desired purpose is served by the use of "distant" signals, which warn a driver of the state of the road two sections ahead instead of one section only; but usually "overlap" is also provided for, so that a train does not release the signal controlling the entrance to the section behind it until it is some distance into a new section, thus giving some latitude for possible overrunning. Train stops are also frequently fitted, by which the brakes on a train are automatically applied by means of a device alongside the track, and which acts in conjunction

FIG. 8.—ELECTRICALLY-WORKED SIGNALS. W. R. SYKES SYSTEM

with the signals in case a driver passes a signal at "danger."

On the subway section of the Interborough Rapid Transit Company, the recently completed underground railway system which has done so much to solve the transport problem in New York, alternating currents are used for the signaling, so as to avoid all possibility of disturbance due to the large direct currents necessarily passing through the traction conductors in view of the enormous traffic carried. A special system of overlaps had to be devised, as it was desired to make the sections very short—in fact, not exceeding double the maximum length of a train.

Automatic signaling according to the system introduced by the British Pneumatic Signal Company, Limited, is in use on part of the main line of the London & South Western Railway for intermediate sections, and Fig. 3 illustrates diagrammatically the arrangement employed.

As shown, a train has passed signal 3 and entered section 3, thus short circuiting a track battery B^3 and cutting out the relay B^3, which is, therefore, de-energized so that its armature A^3 falls by gravity, breaking a circuit, whereby M^6 is de-energized, thus permitting compressed air, which has been holding the signal motor of No. 3 "home" signal in the safety position, to escape, and then allows the signal to go to the "danger" position by gravity. In going to "danger" the circuit breaker C^5 is opened, de-energizing the magnet M^5 and operating the pneumatic valve of signal motor M^5 so that the "distant" signal goes to "danger." Circuit breaker C^6 is also opened, thus interrupting the circuit of magnet M^3 and distant signal No. 2. In addition, No. 2 distant is held at "danger" as the circuit is broken at A^3. As soon as the train has cleared block 3, the circuit from rail to rail is re-established, the current from battery B^3 is sent through and re-energizes relay coil R^3, the armature A^3 is attended and re-establishes the signal circuit which will re-energize magnet M^6, thereby opening the pneumatic valve on M^6. It also puts No. 4 signals to "danger" through the de-energizing of relay R^4 and the opening of circuit breakers C^4 and C^8.

By opening circuit breaker C^8 the circuit of distant signal No. 3 is opened, and that signal is held in the caution position. In this arrangement no overlap is provided for, as the employment of distant signals serves the same purpose.

To enable signals to be worked automatically at night, or at times when no shunting operations are to be carried out, the arrangement shown in Fig. 4 is employed. When the cabin

is closed for manual operation all the main line running signal levers are reversed and signals lowered to the safety position. The king lever *A* is then reversed, thereby locking all signal levers through the mechanical locking. When a train enters the track circuit past the signal the electric relay R^3 is de-energized, breaking the circuit *A B C* at contact *e*, thus de-energizing the electro-magnet *P*, which opens the cut-off valve *G* and admits air to a replacer cylinder on signal lever *B*.

This lever is, however, held by the mechanical lock on the king lever so that the lever *B* is not replaced, but the signal is put to "danger" by the air pressing through the valve *G* operating the cut-off valve *Z*, the action of which cuts off communication between pipes *Q* and *L* and exhausts pipe L, under the diaphragm *R*, thereby allowing the signal to go to "danger." At the same time, the air passing through the electro-magnetic cut-off valve *G* acts on the relay *V* and admits air from pipe *Q*, this air operating on the slide valve *T*, closing the opening *H*, and passing along pipe *M* to operate relay *D* and admit air to the upper end of the cylinder *S*, ensuring the arm being put to "danger." When the train has passed out of the section the electric relay R^3 is energized, and circuit *A B C* is made through the electro-magnet *P*, which, by closing the valve *G*, exhausts the air from under the diaphragm of the cut-off valve *Z*, and the relay *V* admits air from the pipe *Q* to the pipe *L*, and so to the relay *R* at the signal. At the same time, the air supply is cut off through relay *V*, the pipe *M* operating the relay *D* is exhausted, the air on the upper end of the cylinder *S* is also exhausted, and the signal is cleared again automatically.

As regards other automatic systems, interest consists mainly in the apparatus employed, and, therefore, specific reference to the systems of the Hall Signal Company, the General Electric Company, the General Railway Signal Company and others must be reserved for consideration of the specific apparatus.

The "Crewe" system of the Railway Signal Company of Fazakerly, Liverpool, is an almost exact correspondent to manual practice; for although signals and points are operated electrically, the interlocking frames used are mechanical frames in miniature, and the main difference from manual practice is that detector and like checks are provided electrically, and the ordinary signaling instruments are involved with the electrical signaling arrangements. Fig. 5 illustrates the interior of Mr. Severas' junction signal cabin, Fig. 6 shows a signal motor, and Fig. 7

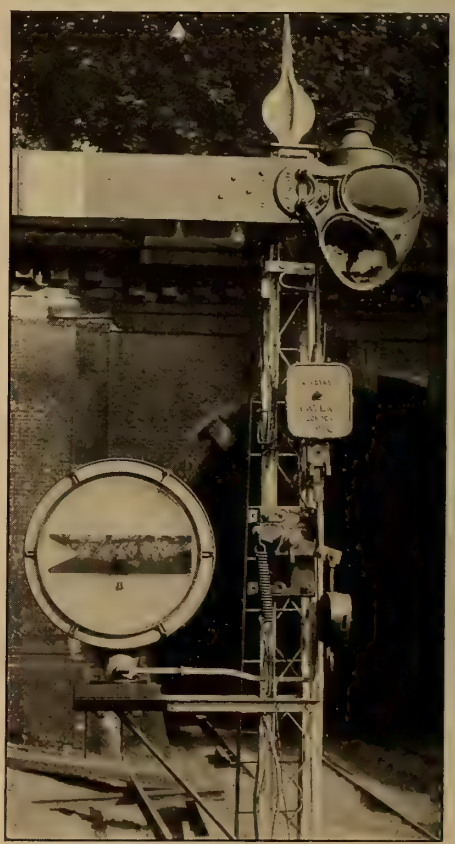


FIG. 9.—"BANNER"-TYPE "DISTANT" SIGNAL AT ENTRANCE TO SYDENHAM TUNNEL. SYKES SYSTEM

illustrates a point motor and detector box and a disc signal.

The signal motor is of the solenoid type, acting through the usual counterweighted-lever operating mechanism with a contact box below. In the case of disc signals the motion of the solenoid case is mechanically converted into a rotary motion of the lamp.

For operating the points the motor, located in a sunk casing alongside, rotates a cam wheel through the worm-reducing gearing, and this cam wheel actuates the point rods. On the other side is a detector box containing contacts, which are only made when the points have been correctly moved, and which provide for a return indication in the signal cabin and for the control of various circuits.

The interlocking is of the usual tappet type, but in miniature, and is arranged below the floor of the cabin.

The apparatus introduced by the W. R. Sykes Interlocking Signal Company, Limited, of London, is also a direct correspondent with manual practice, and in most cases, while the signals are operated electrically, the points are operated mechanically, with, however, various refinements, such as route levers, which control or effect a series of point operations to set a particular route, selector

FIG. 10.—ELECTRO-MECHANICAL SIGNAL FRAME IN SHUNTING CABIN AT VICTORIA STATION. W. R. SYKES INTERLOCKING SIGNAL COMPANY, LTD., LONDON, S. W.

FIG. 11.— ELECTRICALLY-OPERATED POINTS AT VICTORIA STATION, LONDON. W. R. SYKES SYSTEM

mechanisms by which one lever can be made to serve two or more purposes, according to what is being done, and signal replacers and other adjuncts whereby a train assists in its own signaling. This firm is also responsible for the use of what are called "banner" signals in place of disc signals for shunting purposes, and in some cases in place of starting signals, when more convenient than semaphores. The largest power installations which have been carried out are those at St. Enoch Station, Glasgow, and at Victoria Station (London, Brighton & South Coast Railroad), in London; but a number of smaller plants have also been carried out. This firm has also equipped a section of the London Metropolitan Railway with automatic apparatus, "banner" signals being used at the stations and tunnel signals between.

Fig. 8 illustrates a signal post as fitted at Victoria Station, in London. At the foot of the post is a shunting signal of the "banner" type, and on the further platforms several "banner"-type signals are shown carried by a post, the larger ones being used as platform "starters" and the smaller ones for controlling shunting movements.

Fig. 9 shows a "distant" signal of the "banner" type as fitted at the entrance to the Sydenham Hill Tunnel (South Eastern & Chatham Railway) to indicate the position of an automatic signal installed about halfway through this long tunnel.

Fig. 10 shows the interior of one of the shunting cabins at Victoria, this photo being selected in preference to one relating to the larger cabins as illustrating the arrangement better.

Fig. 11 illustrates the mechanism used for electrically-working points as fitted at Victoria Station.

The semaphore signals are operated through ordinary mechanism from an electric motor mounted at the side of the post near its base. When the travel of the operating rod has been completed a circuit is completed, so that a holding magnet is energized, and this holds the signal at "line clear" until the circuit is broken, when the arm returns to "danger" by gravity. The corresponding circuits of the block tele-

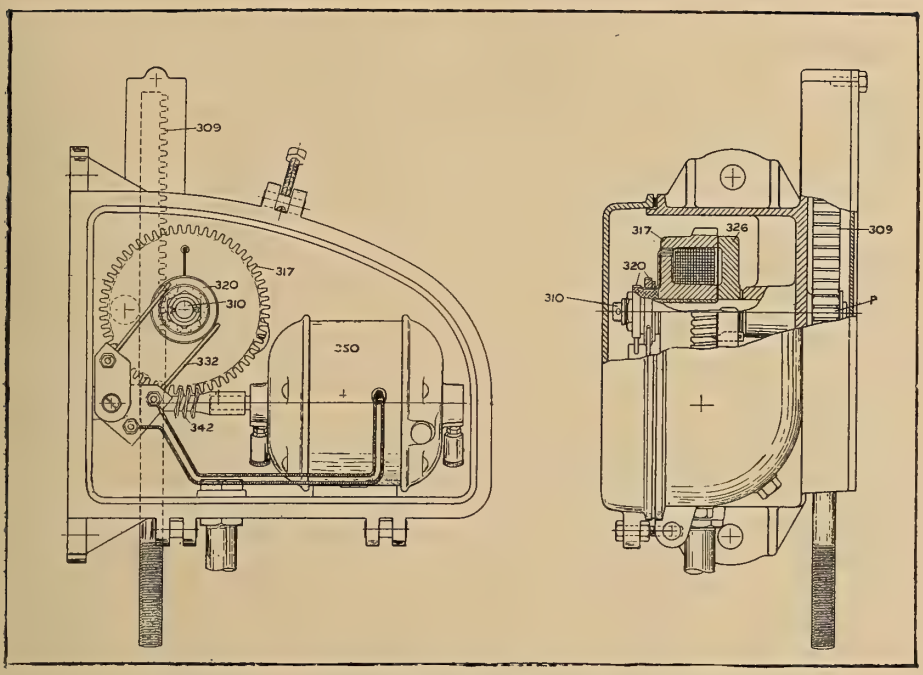


FIG. 12.—SIEMENS MODIFIER SIGNAL APPARATUS. SIEMENS BROS. & CO., LTD., LONDON

FIG. 13.—SIGNAL FRAME READY FOR ERECTION AT SNOW HILL STATION, BIRMINGHAM. SIEMENS BROS. & CO., LTD., LONDON

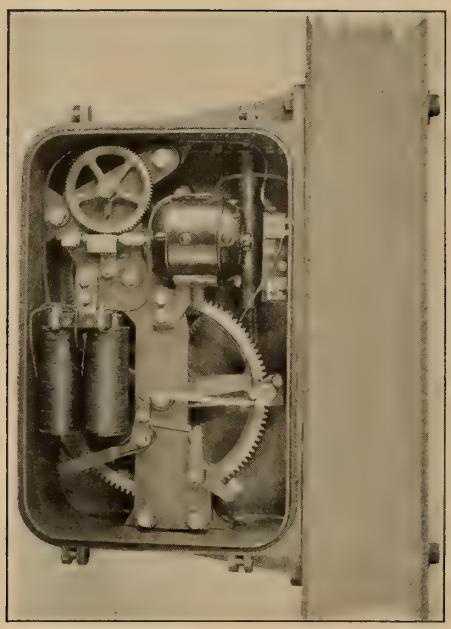


FIG. 14.—BATTERY SIGNAL MACHINE. SIEMENS BROS. & CO., LTD., LONDON, S. W.

graph instruments are carried through the signal arms, and if the semaphore is not properly at "danger" the current is short circuited. Electric treadles are fitted on the track in advance of each signal. The system also provides for the automatic replacement of a signal arm by the passage of a train over an electric treadle, even if the signalman should omit to do so. The signalman can return an electric slide or lever sufficiently far to return a signal to "danger"; but until the train has passed over an electric treadle the slide or lever cannot be completely returned, and, therefore, the interlocking is held until the purpose of the signal has been fulfilled.

The banner or arms of the shunting signals, which consist of light frames covered with red cloth, are each mounted on a spindle attached to an armature, which is influenced by a pair of coils which attract it to incline the arm as required, while the pivot of the arm is so located that as soon as the coils are de-energized it returns to the horizontal position.

On the Waterloo & City Railway, in London, there are no intermediate stations, but intermediate signals are provided, and these are of special tunnel type and power-operated, though controlled from the terminal signal boxes.

For operating the points the general features of mechanical operation are retained, but the points facing point locks as locking bars are all operated by one motor action.

On the Great Northern & City Railway, in London, the signals are automatically controlled, but are very simple in construction. They consist merely of two electric lamps fitted one above the other in a casing, with a red glass in front of one and a green glass in front of the other, and the respective lamps are switched in or out alternately as controlled by the track contacts.

Messrs. Siemens Brothers & Co., Limited, have also fitted several all-electric power signaling plants at busy centres in Great Britain, and

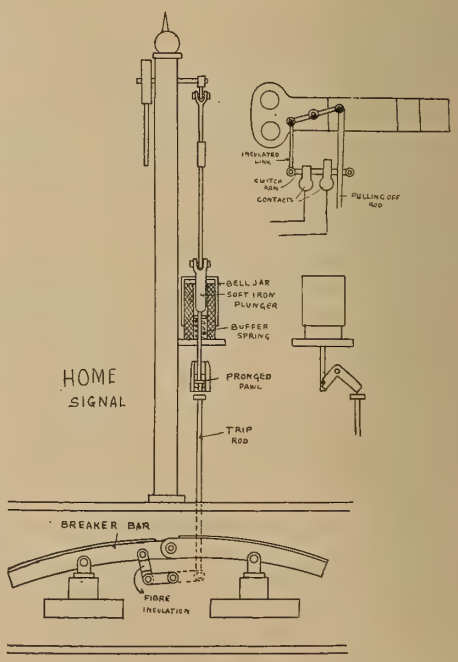


FIG. 15.—DIAGRAMMATIC VIEWS OF SIGNAL APPARATUS USED IN LIVERPOOL OVERHEAD RAILWAY

FIG. 16.—THREE-POSITION SIGNALS OF THE UNION SWITCH & SIGNAL COMPANY, SWISSDALE, PA.

their apparatus involves signal and point operating mechanism, and, in fact, covers the whole field of power signaling, though only brief and incomplete reference is possible in this article. There are considerable differences in the various installations carried out by Messrs. Siemens Brothers, owing to the fact that each plant has largely been designed on its own merits.

Messrs. Siemens Brothers were the first to introduce into Great Britain what is known as the permanent control system, and the installations at Derby (Midland Railway) and Didcot (Great Western Railway) are so equipped. With this system the levers, such as are not mechanically interlocked, can be pulled over or replaced completely, so that, for instance, a certain route having to be formed, the point mechanisms can be working simultaneously without having to make successive movements of the operating machines by the levers in the frames.

In this system small repeaters are situated immediately under the levers in the frame and indicate by constant current at 32 volts the condition of the respective apparatus governed by the levers above them.

The grouping up of the signal currents is so arranged that, after a certain route has been correctly set, electric locks are released from the signal levers connected for it.

Recently the firm has brought about a simple check lock system, and the installation at Birmingham (Snow Hill) is worked on this method. With this system the point levers can be at first moved only about

three-quarters over, and it is only when the desired movement has been properly made that a return current is completed, which releases the check lock and allows the lever to be moved the remainder of its stroke.

The usual design of signal machine now used is seen from Fig. 12. The motor drives a worm-wheel through worm-gearing, and this worm-wheel, which is frequently mounted on its shaft, carries a revolving coupling-magnet. A circular armature is keyed upon the shaft and is in contact with the worm-wheel magnet. Upon the current being joined up, the motor revolves and the worm-wheel magnet is energized, whereupon it attracts its armature, which is forced to rotate with it, and the connecting levers which actuate the semaphore arm are moved through rack and pinion mechanism. As the semaphore arm reaches the "line clear" position, it mechanically opens a switch located in a switch box, and this cuts out the motor; but the signal is held by the coupling magnet until the lever in the locking frame is replaced or the circuit is opened by any other means.

In some cases, where several semaphores are carried by the same post, a selector mechanism is employed, whereby one motor serves for operating all the arms, the selection of each particular semaphore being controlled by the energizing of the respective coupling magnets, according to the movements which have been made. In a few instances multi-indication, single-arm semaphores have been installed, in which one semaphore arm serves for several routes, the particular route being shown in a frame in which figures or words are exhibited to indicate which route has to be set.

In the case of point mechanisms, the motor is arranged horizontally alongside the points in question and by worm-gearing drives a worm-wheel, which actuates the points through crank mechanism. For facing points, the worm-wheel has a total rotation of about 320 degrees, and by appropriate lever mechanisms connected with the locking device and with the usual locking bar the latter is raised and the lock released, the points moved, and the lock again applied during this rotation of the worm-wheel.

For trailing points the mechanism is, of course, much simpler, and the arrangement is such that they can be trailed through without damaging the mechanism.

Fig. 13 shows the signal frame ready for erecting at Birmingham.

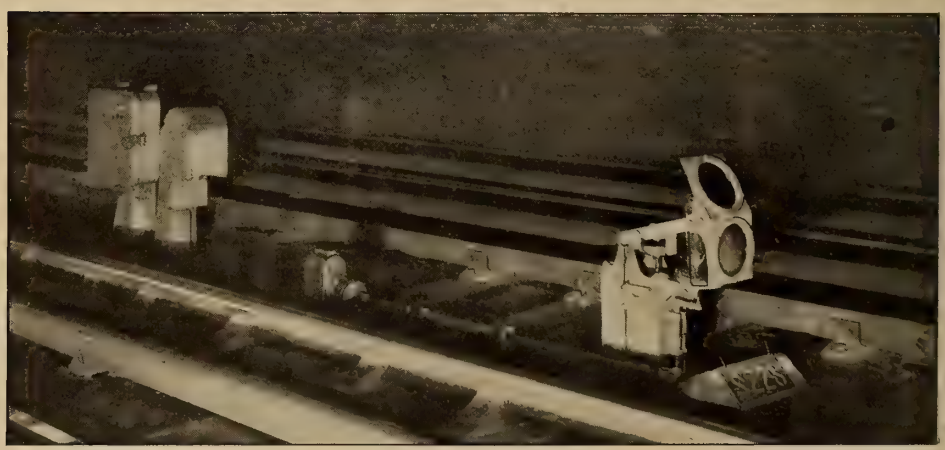


FIG. 17.—WESTINGHOUSE ELECTRO-PNEUMATIC TUNNEL SIGNAL, TRAIN STOP, AND RELAY AND RESISTANCE BOXES ON DISTRICT RAILWAY, LONDON

The frame is 34 feet 6 inches long, and there are 224 levers.

Messrs. Siemens Brothers have recently introduced a battery signal-machine which is particularly adapted for use when isolated signals are installed for breaking up a long section, operating more or less automatically, under the control of track circuits, or operated by signalmen at the rear and replaced and controlled by the passage of a train through treadles or contact devices, or in cases where electric power is not available and the installation of a special plant is not justified.

Fig. 14 shows the mechanism of such a signal, which is operated by primary batteries located in a case at the base of the post. The operation is mainly dependent upon a half axle, which engages with the teeth of a large spur wheel rotated by the motor. This half axle is carried by a crank arm, and is held locked by means of a system of levers from the holding-off armature. When the signal movement has been completed the motor circuit is broken, but the holding-off coil retains its armature so long as current passes through it, and this keeps the signal at "line clear." When the holding-off current is broken, the armature drops, as shown, and the signal arm is free to return to "danger" by gravity.

Reference has already been made to the system of signaling recently introduced on the Liverpool Overhead Railway, and Fig. 15 shows the ordinary construction of home and starting signals. The breaker bars are in two sections, hinged together at an obtuse angle, and when the shoe of a train comes in contact therewith the two portions of the bar are depressed into a nearly level position. By means of the mechanism shown, a trip rod is forced upwardly and operates a catch *H*, so that its catch end ceases to engage a pin *I* on a rod *G*, which is a continuation of the signal operating rod. The semaphore is, therefore, released, and moves by gravity to the "danger"

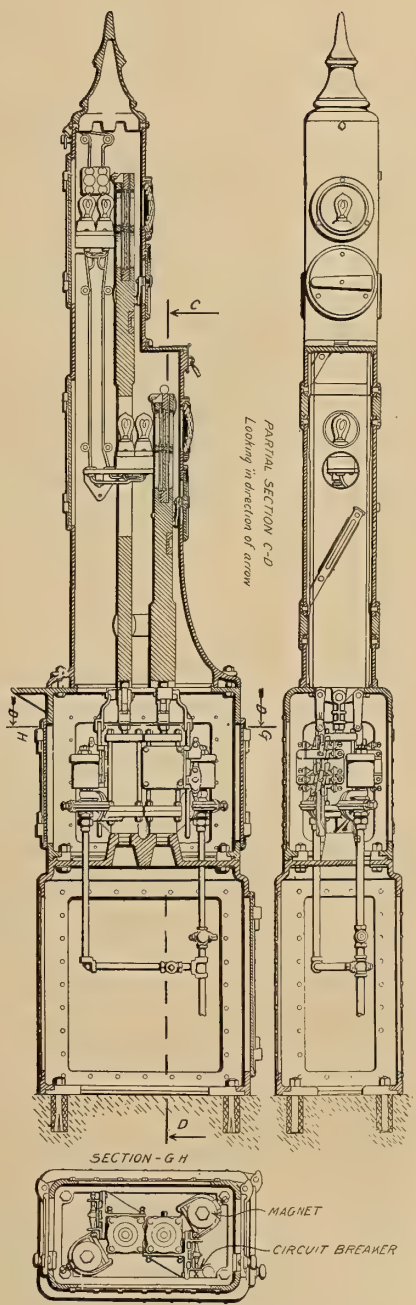


FIG. 18.—DETAILS OF THE STANDARD SUBWAY BLOCK SIGNAL

FIG. 19.—ELECTRO-PNEUMATIC POINT MOTORS. UNION SWITCH & SIGNAL COMPANY, SWISSDALE, PA.

position. When the operating circuit is completed by the proper maker bar ahead the iron-clad solenoid magnet attracts a soft-iron core on the signal rod, thus pulling the semaphore to the "clear line" position. The catch *H* then re-engages the pin *I* and holds the signal off until again released by another train. At stations the home signal circuits are carried through a switch on the starting signal, so that the home signal is not released, although it is put to "danger" on its own account.

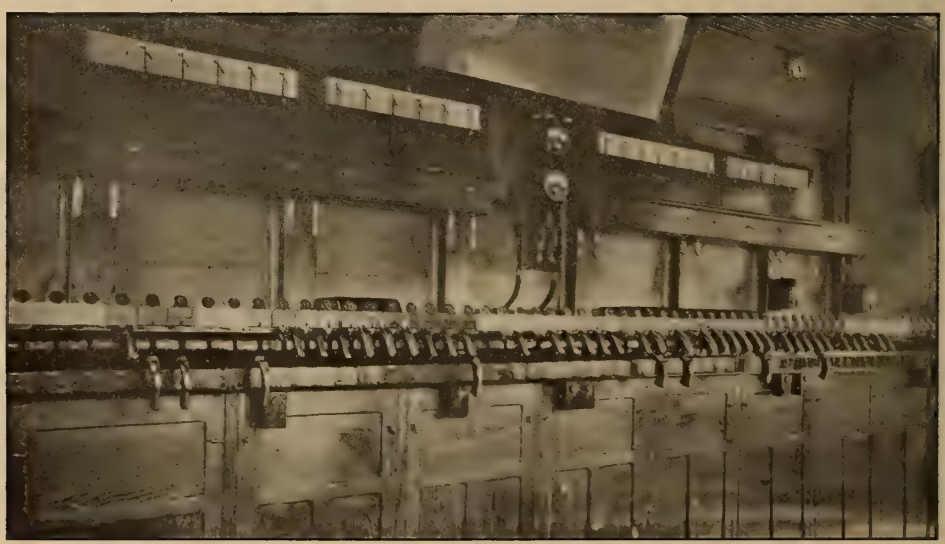


FIG. 20.—OPERATING FRAME AND INDICATORS. UNION SWITCH & SIGNAL COMPANY

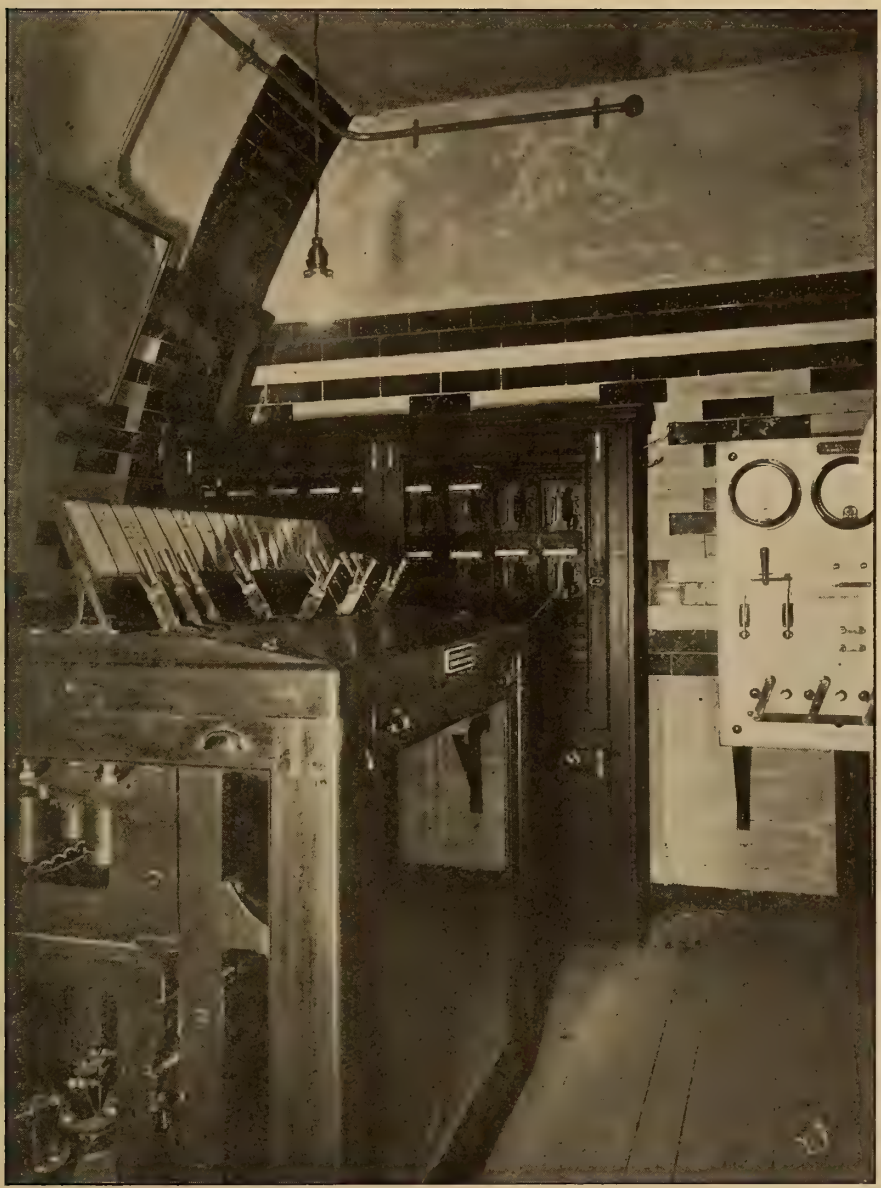


FIG. 21.—ELECTRO-PNEUMATIC AUTOMATIC SIGNAL CABIN. MACKENZIE-HOLLAND AND THE WESTINGHOUSE POWER SIGNAL COMPANY, LTD., LONDON

At some of the intermediate stations crossovers are provided; but these are not used regularly, so that somewhat elaborate arrangements for signal control when they are used are permissible. An Annett's key is employed for each signal, and the operating levers for the crossover points in the signal box cannot be operated until the Annet's keys from the home signals in both directions have been inserted in the frame. To withdraw each key from the signal, it must be turned sufficiently to raise a slotted bar, whereby the automatic mechanism is put out of re-

turn and the signals remain at "danger" so long as the crossover is in use.

Arrangements of this character will not, of course, suffice except where traffic is straightforward and where there are no complications; but they have proved very satisfactory on the Liverpool Overhead Railway.

The Westinghouse firms (Mackenzie & Holland and the Westinghouse Power Signal Company, Limited, in Great Britain; the Westinghouse Brake Company and associated firms for Continental work, and the Union Switch & Signal Company, in the United States) employ both an electro-pneumatic (high-pressure) system and an all-electric system.

Their systems cover the whole ground of power signaling, and are probably more used than any others. Fig. 16 shows an installation recently carried out by the Union Switch & Signal Company at Sterling, Ohio.

Dealing first with the Westinghouse electro-pneumatic apparatus, which has been most extensively employed in large-scale installations, in this

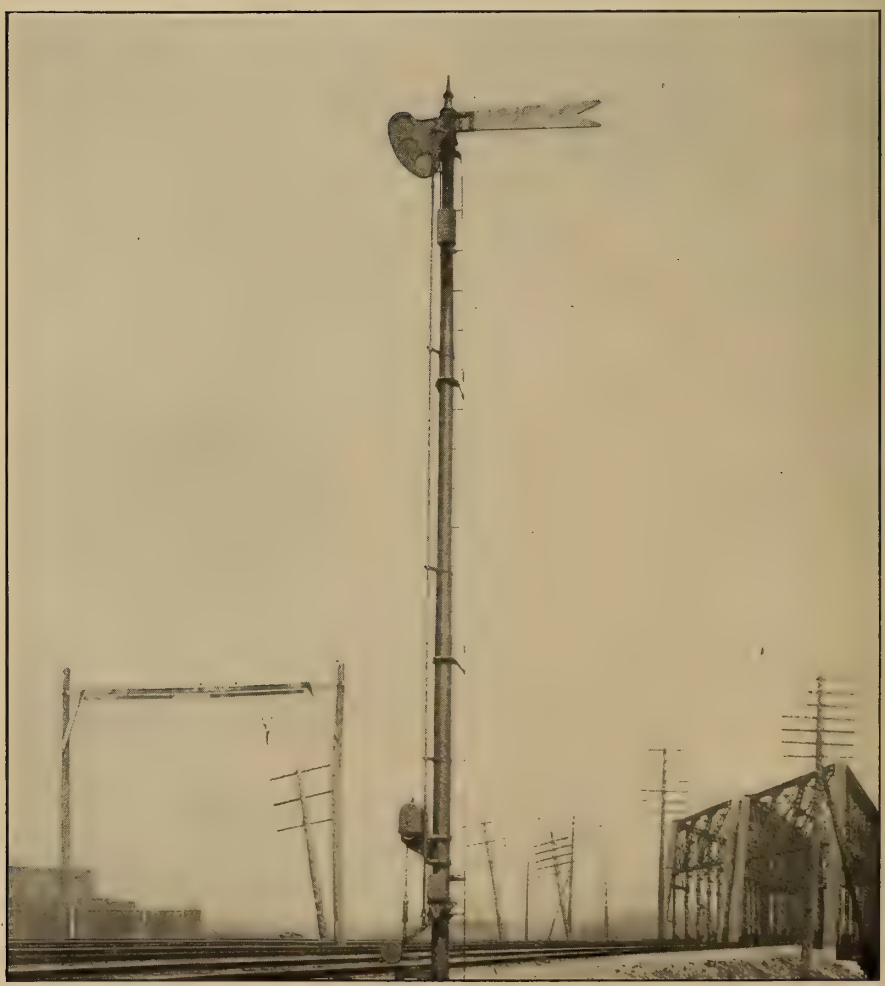


FIG. 22.—TAYLOR ELECTRIC SIGNAL, CHICAGO & ALTON RAILROAD. GENERAL RAILWAY SIGNAL COMPANY

FIG. 23.—SPINDLE-TYPE MECHANISM POSITION SIGNALS. GENERAL RAILWAY SIGNAL CO., ROCHESTER, N. Y.

class of apparatus the control is effected by weak currents, which may be supplied from a circuit or from primary or secondary batteries; but the actual operating power is provided by compressed air, all the motors being supplied from mains extending from a compressor plant, the pressure usually being about 65 to 75 pounds per square inch, though the volume of air used by each motor is very small.

When air is admitted to the motor cylinder by means of the electromagnetic valve, the semaphore is forced to the "line clear" position, and as soon as released the arm returns to "danger" by gravity. A circuit breaker is operated directly from the signal arm. In the case of distant signals their controlling circuits must be properly completed at the "home" signals they repeat in advance, and by "home" or "starter" signals under which they may be placed, so that all possibility of conflicting indication is avoided; but they have their own compressed-air motors. In some cases selected signals are operated by one lever, according to the position of the points concerned. For tunnel purposes a double spectacle is employed, as shown in Fig. 17. Several designs of tunnel signals are in use, to meet various requirements.

In signaling the Interborough Railway in New York, special constructions of the signals had to be adopted, partly owing to the character of the signaling and partly because of the limited space available. Fig. 18 illustrates the apparatus employed. Behind the lenses is a vertically-moving slide having two glasses, red (or yellow for "distant" signals) above and green below, and these slides are raised by pneumatic motors (controlled electrically) to exhibit a green indication, while the normal tendency is to fall and show red or yellow. As a rule, each casing has both a "home" and a "distant" signal, the former above the latter. In addition, small semaphores are fitted, actuated in conjunction with the moving slides, so that a position indication is given in addition to a colour indication; but these arms are small.

For operating the points, a com-

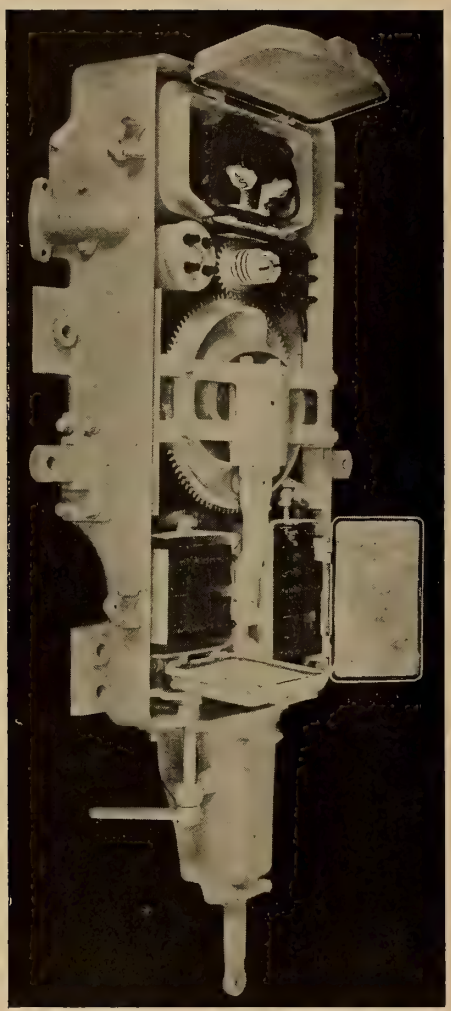


FIG. 24.—SWITCH MACHINE OF THE GENERAL RAILWAY SIGNAL COMPANY

pressed-air motor is similarly employed under electric control, and Fig. 19 shows a series of point motors as recently installed at Sterling, Ohio. The mechanism embodies point locks, etc., as usual, together with the necessary contact devices, which cannot be referred to in detail here.

Fig. 20 illustrates a Westinghouse operating frame with indicators above, as installed by the Union Switch & Signal Company.

Fig. 21 shows the interior of a signal cabin on one of the London tube railways with Westinghouse electro-pneumatic equipment. Part of an illuminated track diagram is shown, whereby the movements of trains are represented by the completion or breakage of lamp circuits behind the diagram of tracks corresponding with the track circuits. In this particular case it is worthy of note that this station was temporarily used as a terminal before the construction of the line was completed, and as all trains then used a platform not visible to the signalman, the whole traffic was conducted without his ever seeing a train.

Such illuminated diagrams are fitted in many of the junction cabins on automatic railways, particularly on underground and other lines with very heavy traffic, and they have proved of very great value in assisting the work of the signalmen.

The Westinghouse firms have also done a good deal of work in connection with purely electric signaling. On the Great Western main line electric automatic signals have been installed, in order to break up a long

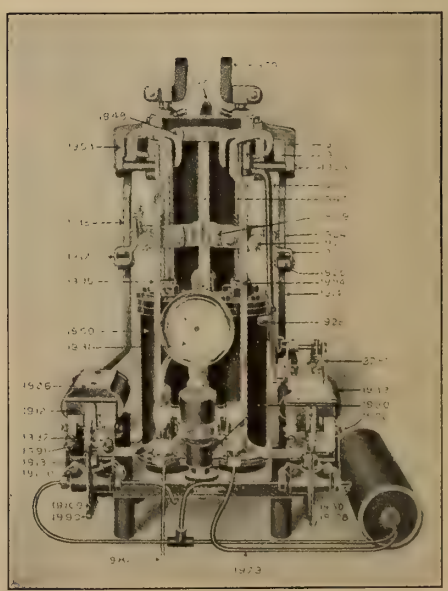


FIG. 26.—DOUBLE GAS MECHANISM, HALL SIGNAL COMPANY

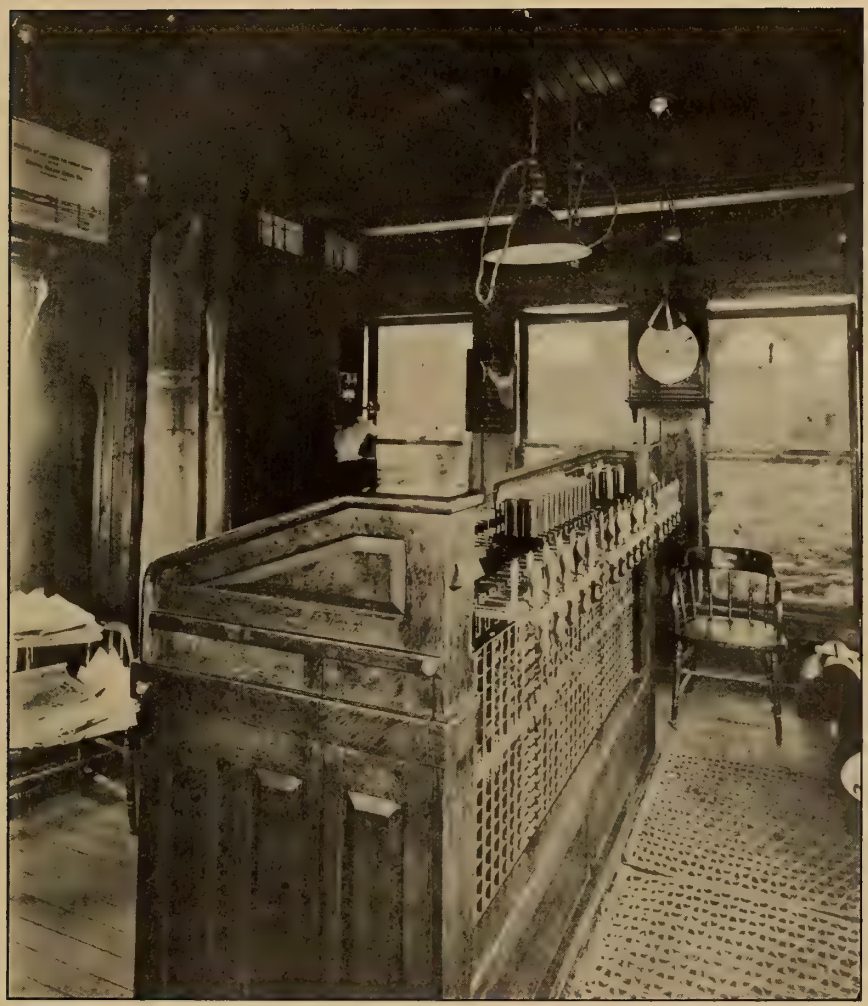


FIG. 25.—INTERLOCKER HIGH BRIDGE TOWER, MADE BY THE GENERAL RAILWAY SIGNAL COMPANY, WITH FRONT COVER REMOVED

section. They are actually operated by the signalmen at the ends of the long section, but are returned to "danger" by the passage of a train and are locked by the track circuit ahead while the section is occupied.

Electric semaphores and discs have been somewhat extensively employed in America under more or less similar circumstances, and they have also been adapted to some extent for automatic operation.

In the case of an installation recently carried out at Yarnton Junction (Great Western Railway) a very compact electric mechanism is employed. The motor drives a spur wheel by worm-gearing, and this is clutched with the semaphore operating mechanism by electric clutch devices. When the semaphore reaches its lowest position the motor is cut out and the clutch is held by a holding-off coil until released to allow the signal to go to "danger." The coils being provided are of low resistance for pulling off, and are of high resistance for holding off.

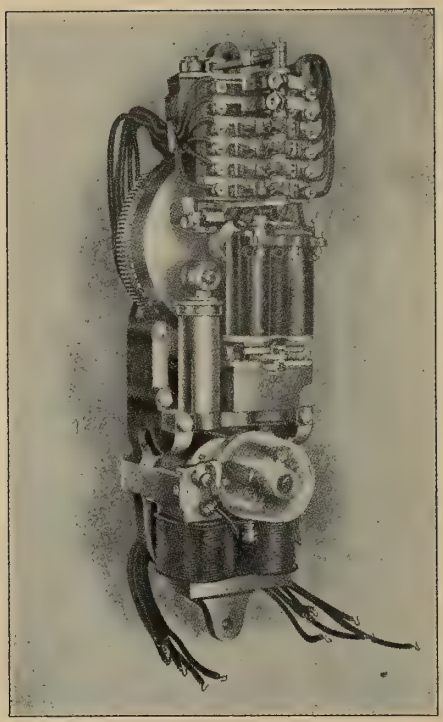


FIG. 27.—SINGLE-ARM ELECTRO-SEMAPHORE MECHANISM, HALL SIGNAL COMPANY, NEW YORK

The Taylor Electric Signal Company did a good deal of pioneer work in the States, and their apparatus is still in use; but in the hands of the General Railway Signal Company, of Buffalo, N. Y., U. S. A., together with the systems of the Pneumatic Railway Signal Company, of Rochester, N. Y., and the Standard Railroad Signal Company, of Troy, N. Y., the earlier systems have, to some extent, given place to later and improved apparatus, though this is more particularly true in connection with automatic signaling, as the systems mentioned are still employed for new work other than automatic.

Fig. 22 illustrates a Taylor single-arm electric signal. The motor is connected by a train of gears with a pulley sheave and winds up the chain thereon, so as to lift the counterweighted lever which operates the semaphore. The return is effectuated by gravity.

To enable one motor to operate two independent signals, one chain is fitted upon its pulley so that it will be wound thereon when the motor rotates in one direction, and the other chain will be wound up when the motor rotates in the other direction, the respective pulleys being connected with the driving shaft by clutch or ratchet devices, according to the direction to which they must respond. As two-arm signals of this class usually control splitting points, the armature connections are controlled by the point mechanism, so that one lever in the signal cabin will operate either signal. In the case of single-arm posts the motor rotates in one direction only. In some cases hook-selector mechanism is employed, whereby one motor will actuate two, three or more semaphores, as controlled by the electric

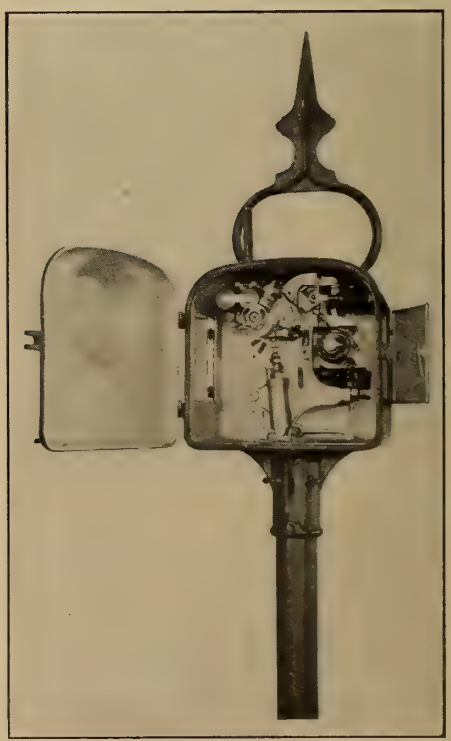


FIG. 28.—GENERAL ELECTRIC SPINDLE-TYPE SIGNAL MECHANISM

coupling devices of the selector mechanism.

The General Railway Signal Company, of Rochester, N. Y., have since introduced a special signal mechanism of their own, mainly intended for automatic installation. In this apparatus the signal-operating mechanism is situated adjacent to the semaphore itself, as shown in Fig. 23.

Three-position signals, with the arm moving upwardly instead of downwardly, are also largely employed; but the mechanism is correspondingly designed.

Fig. 24 illustrates one of the latest switch machines installed by this firm, as used on the New York Central Railroad, and Fig. 25 shows a locking frame (Taylor system) with the front covers removed. In every way this system is very interesting; but detailed reference is, unfortunately, not possible.

The Hall Signal Company's apparatus, both all-electric and electro-gas (carbonic-acid gas under pressure is used for operating the motors with electric control), is also adapted for non-automatic signaling, but is mainly used automatically, for which purpose it was one of the first systems giving satisfaction. It is particularly adapted for isolated use, as for splitting up long sections, and is largely used in this way, as well as in more extensive installations. There are one or two installations in Great Britain and a number in Germany; but it is mainly in America that Hall signals are used, where they are numerous. The gas is used at a pressure of about 60 pounds per square inch, and the admission and exhaust of the gas cylinder are controlled by electro-magnetic valves. An electro-magnetic clutch holds the signal in the "off" position until the control circuit is broken. A double gas mechanism is shown in Fig. 26.

The Hall Signal Company has also done a good deal of work in connection with all-electric apparatus, usually in connection with automatic installations.

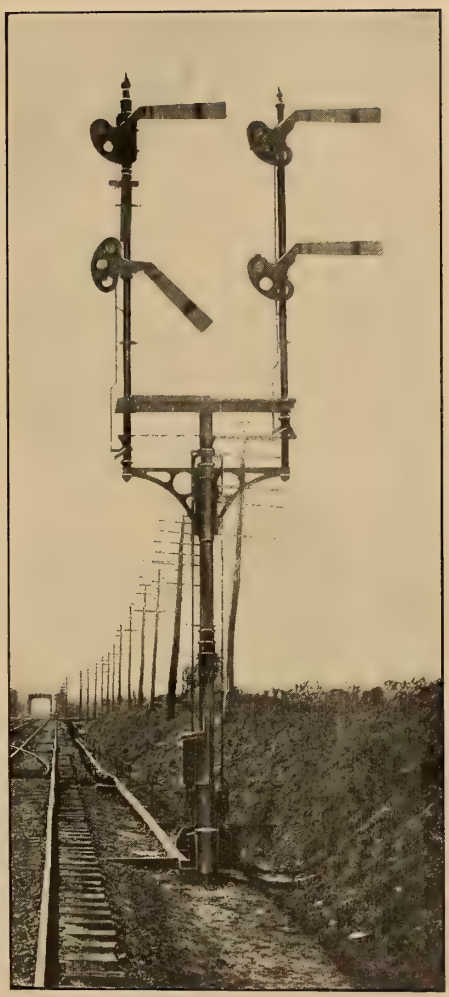


FIG. 29.—GENERAL ELECTRIC TOPMAST, THREE-POSITION SIGNAL ON BALTIMORE & OHIO R. R.

Fig. 27 illustrates the mechanism employed for single-arm signals. The motor revolves a rotating disc through gears, but to connect it with the semaphore operating means a rotating armature, which rotates until the disc has to be attracted and held to a rotating clutch magnet, and it is only when all three are held together by the energizing of the clutch magnet that the semaphore is moved to "line clear." The rotation controls the circuits in question, but for holding off the signal an oil cylinder is employed under electric control.

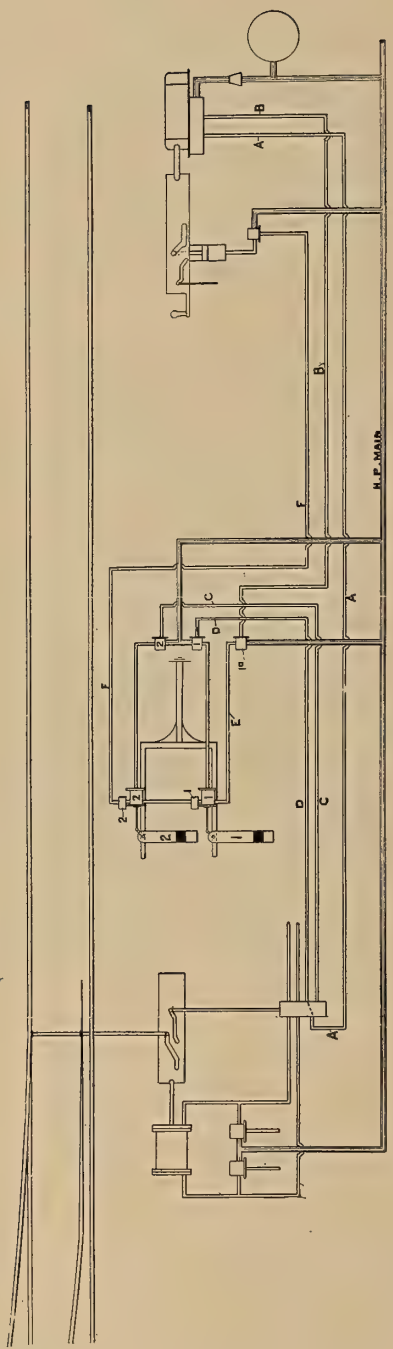


FIG. 30.—DIAGRAM OF SELECTED SIGNAL. BRITISH PNEUMATIC SIGNAL COMPANY, LTD., WESTMINSTER, S. W.

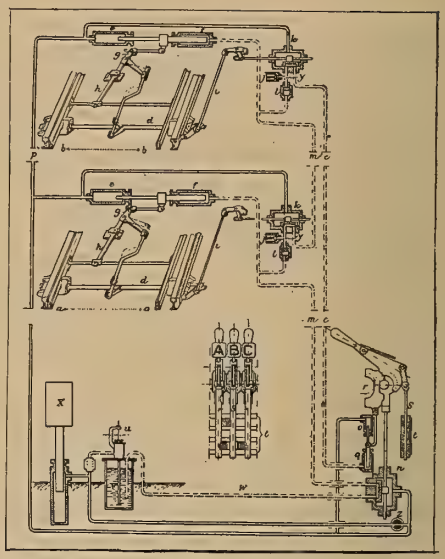


FIG. 31.—DIAGRAM OF HYDRAULIC SIGNAL SYSTEM OF SAXBY & FARMER, LONDON

When two or more arms are placed on one post, and particularly when there is a "home" signal and a "distant" below it, both arms are operated by one motor.

The Hall Signal Company have recently equipped a section of the Long Island Railroad with alternating-current track circuits to provide for special conditions. The signal motors themselves are operated by direct current from storage batteries charged from the conductor rail through resistances; but in one case a rectifier is employed connected with the alternating-current supply through the regular relay transformer, whereby direct current at 12 volts is provided for signal operation.

The General Electric Company, Schenectady, N. Y., have also introduced electric signals, in which the operating mechanism is placed on the signal post contiguous to the semaphore, and Fig. 28 shows the mechanism thereof as adapted for three-position signals (Fig. 29). The mechanism comprises a motor, reduction gears, means for engaging and disengaging the signal shaft for the driving gear, means for preventing shock as the signal returns to "dan-

ger" by gravity, and the necessary electric contact devices.

The British Pneumatic Signal Company, of London, has done a considerable amount of work with wholly pneumatic apparatus (low pressure); but this, of course, in direct replacement of manual power. The apparatus is also employed in conjunction with electric control for automatic and semi-automatic purposes, as explained in due course. A large number of their installations have been in use for some years on the London & South Western Railway, and several sections of the main line are adapted for automatic or alternative-automatic and semi-automatic operation. The system has also received special adaptation, as at the recently constructed "hump" sorting siding at Wath, on the Grand Central Railway.

Fig. 30 illustrates pneumatic signal apparatus as installed by the British Pneumatic Signal Company. Several kinds of practice are employed for different requirements, but a selected signal installation working in conjunction with the points must serve for detailed reference in view of space limitations. For operating the signals air, at about 15 pounds per square inch, is used; but for control air at 7 pounds is developed. As a signal lever is moved in the signal cabin an indicating port is opened; but is closed as soon as the semaphore begins to lower, and air is admitted to a diaphragm relay valve, whereby the operating air is admitted to signal cylinder to lower the signal, in which it remains until the signal lever is moved back. The signal lever can only be moved back for part of its stroke; but when the semaphore has returned to "danger," which is effected by air pressure and not by gravity—that being reserved only for action in case of failure—the air is admitted to a motor cylinder, whereby the movement of the signal lever is completed, thus providing an indication that the signal has responded as required. In the case of splitting signals only one lever movement is employed for both arms, and the arms are selected by mechanism acting in conjunction with the point movements as shown.

In many cases the signals are fitted with replacer mechanisms, whereby the signals are automatically returned to "danger" on the completion of a track contact when a train has passed.

So far as the writer is aware, there is only one firm concerned with hydraulic apparatus (Messrs. Saxby & Farmer, Limited), and this system is comparatively little known, though there is a considerable number of these plants in use, principally in Italy and Russia, but also in Great Britain and the British colonies. For operating purposes a mixture of water and glycerine under pressure is used, and this is conveyed by small pipes to the signal and point motors, double-acting piston motors being used for points and single-acting motors for signals near the signal cabin. In the case of "distant" signals and signals far away, ram cylinders are fitted near the cabin, and these are connected with the signals by wires in the usual manner. Fig. 31 shows diagrammatic views of the various mechanisms.

In conclusion, the writer must acknowledge his indebtedness to the various firms whose productions are described or whose practice has been considered or reviewed, though it has not been possible to utilize a quarter of the material available or which has been supplied for use in the preparation of this article.

TRAMWAY REPAIR WORKS AND MACHINERY.

By C. Pendlebury, M. I. Mech. E.

THE increased speed, economy and reliability of tram cars worked by electricity from a central station have driven the older steam tram cars off the road, and are also causing the gradual extinction of horse-drawn cars wherever electricity is available or can be produced at a reasonable price.

The quicker running and lower fares have done something towards the prevention of over-crowding in large towns by enabling even the lower-paid workmen to live outside the town where they are employed.

A considerable amount of wear on tires, bearings, motors, etc., is caused by the sharp curves and rough roadways inseparable from tramway service, and adequate works and machinery are necessary for repairing the cars and putting them into service again with the least possible delay.

Where only a few cars are in use, the repair work can usually be done in a portion of the car depot set aside for this purpose; but as the number of cars increase, requiring two or more depots for their storage, it is advisable to have only one large repair works, and not to undertake repair at each depot, except small detail work, such as adjusting brakes, controllers, etc., which does not require the use of machinery.

The works can either be adjacent to one of the depots or entirely separate, in a suitable position for receiving the cars and returning them to any section of the service when repaired.

By this method specialized machinery can be used, each workman will become expert in his own particular task, and the repairs can be done systematically; this will reduce the cost, ensure a higher standard of work and up-keep, and minimize the risk of breakdowns in service.

The works shown in Fig. 1 were constructed recently on the advice of the London County Council chief officer, Mr. Fell, to deal with the whole of the cars then in use—about 600—and with ample space to provide for future extensions. The ultimate size of the works is shown, the part shaded being already in use, and extensions now in progress can be erected without interference with the present plant.

The works cover nearly seven acres, and adjoin a branch of the South Eastern & Chatham Railway, from which a siding will be laid into the works.

The works shown in Fig. 2 were originally used by the tramway company for the repair and maintenance of steam cars, but were taken over by the corporation in 1906, when they took charge of the tram service and changed over to electrically-driven trams.

As the works were in a convenient position, they were reconstructed by Mr. A. Baker, the general manager, and fitted with new machinery, making them into a most convenient and up-to-date repair works.

At the present time these works deal with about 300 cars, but are large enough to cope with the considerable increase in cars that will shortly be made to supply other routes coming under the control of the corporation.

It will be seen from the plans of the above works that in each case only a single line is used to enter the

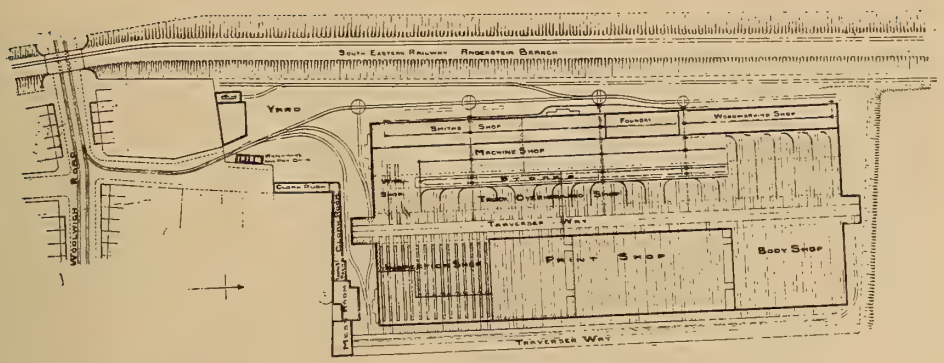


FIG. 1.—PLAN OF REPAIR WORKS AT EAST GREENWICH FOR THE LONDON COUNTY COUNCIL TRAMWAYS

works and the cars are delivered to the bays where they are to be overhauled by an electrically-driven traverser running in a shallow pit.

This is a convenient method, and economizes space; but in many works the cars can be run directly into the desired bay, which takes up rather more room, but does not require the use of a traverser. The latter system is used at Leeds to deal with about 300 cars, where the general manager, Mr. Hamilton, has arranged a complete repair works alongside the Kirkstall road car depot, which is in a convenient and central position for the purpose.

PERIODICAL INSPECTION AND REPAIR OF CARS

The cars are generally taken to the works at intervals of four to six months for inspection, re-turning of tires, and any small repairs that may be found necessary; but they are also thoroughly overhauled at stated periods, when the bodies are renovated, the trucks taken apart, brake gear, motors, gearing, etc., carefully examined, wiring and switches tested for insulation, etc., and any bent or damaged parts renewed. In London the regulations of the Metropolitan Police require this overhauling, which takes about two weeks, to be done

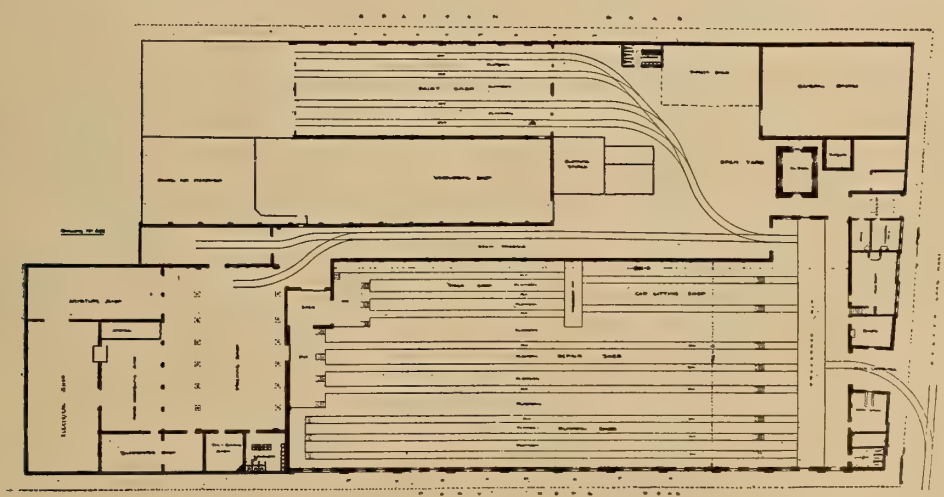


FIG. 2.—PLAN OF THE TRAMWAY REPAIR WORKS OF THE BIRMINGHAM CORPORATION

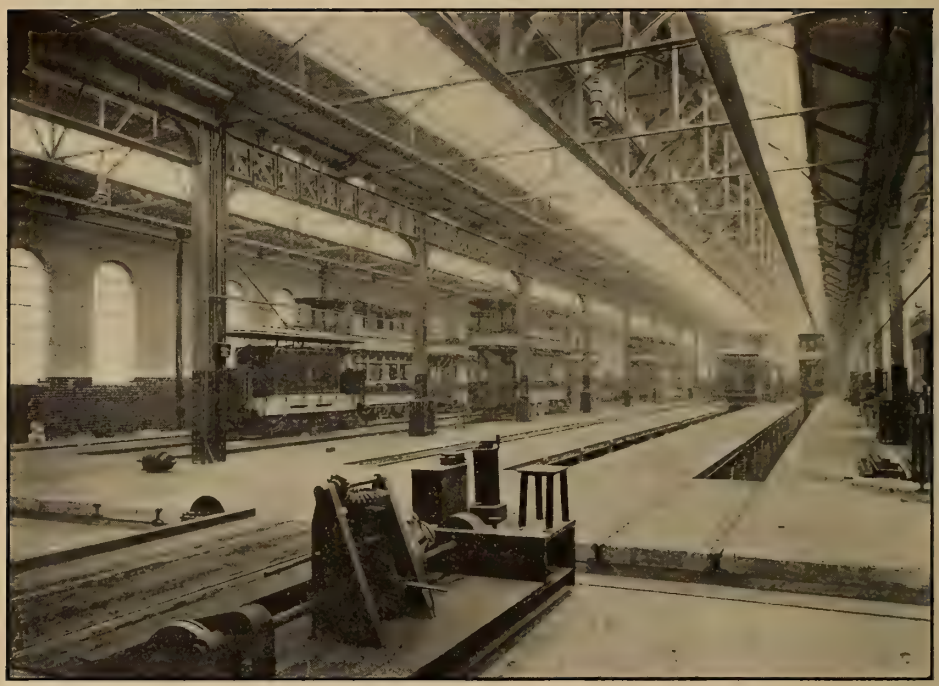


FIG. 3.—BIRMINGHAM CAR REPAIRING SHOP, SHOWING TRAVERSER

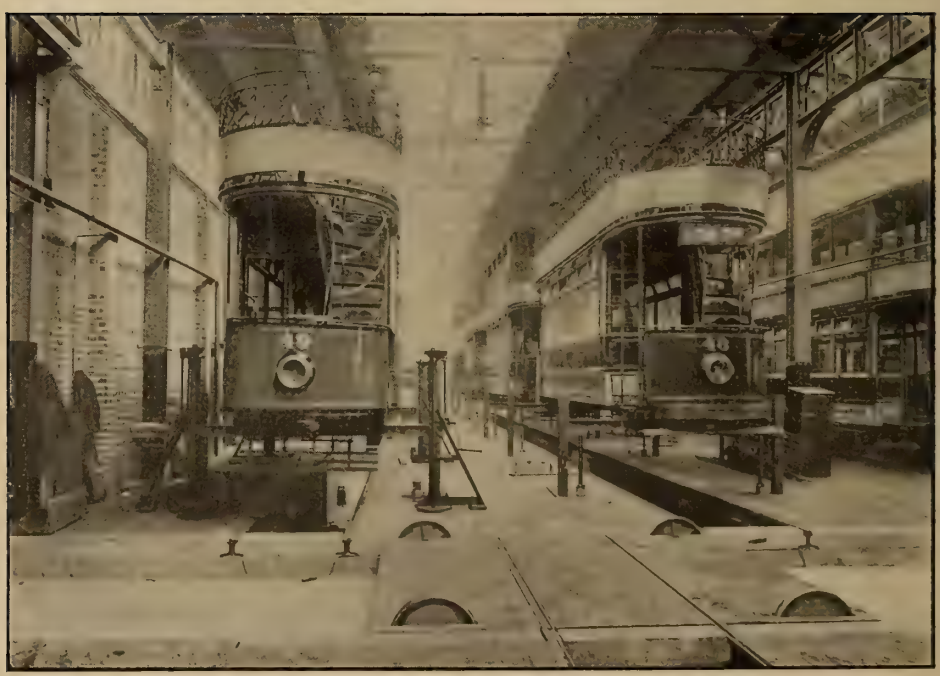


FIG. 4.—BIRMINGHAM CAR REPAIRING SHOP, SHOWING METHODS OF LIFTING CAR BODIES

every twelve months, though elsewhere it has been found that from sixteen to twenty-four months, depending upon the time each car is used, is sufficient to keep them in good and reliable condition.

In dealing with repairs it is customary to issue a separate order for each car, to which all work is charged, and to keep a complete record of the cost and mileage of each car, motor, controller, etc. The repairs of damaged cars is kept separately, so that comparisons can quickly be made between different types and makes of cars.

After a preliminary inspection in the works and a note made of all repairs required, the brake gear, rigging, etc., is disconnected, ready for dismantling. The body is lifted clear of the trucks and the latter taken away by traversers or electrically-driven overhead traveling cranes to the truck shop.

Two methods of lifting the car bodies are shown in Fig. 4, the one on the left being the ordinary type of hand-worked screw frames and cross-beams, whilst the other one has the cross-beams lifted by hydraulic jacks worked from a separate hand pump. To prevent the jacks leaking down, the rams are screwed and fitted with nuts to take the weight of the car bodies, thus combining the high efficiency of the hydraulic jack in lifting with the certainty and safety of the screw jack.

FIG. 5.—LONDON COUNTY COUNCIL TRAMWAYS TRUCK SHOP

In some cases the lifting is done by power; the London County Council Works use pneumatic jacks, and after lifting the car bodies are put on temporary trucks for moving into the body shop. The Leeds City Works use cross-beams raised and lowered by screws, each set of four being driven from an electric motor by gearing beneath the pit, which will raise or lower a car body in less than a minute.

On arrival at the truck shop, the

FIG. 6.—LONDON COUNTY COUNCIL TRAMWAYS PAINTING SHOP

trucks have their motors disconnected, cleaned and taken to the electrical department for attention; the wheels and axles are taken to the wheel shop for re-turning, and all the small parts are thoroughly examined and overhauled. This takes from four to seven days, after which the trucks and cars are reassembled and taken into the paint shop for repainting and varnishing, which, with suitably heated shops, takes about another week.

Fig. 6 shows part of the paint shop of the London County Council Tramways, which is 104 feet long, 112 feet wide, and can be shut off from the other parts of the works by motor-operated roller shutters. The H section columns between the car lines are to enable the painters to work on the cars at any desired height. The columns carry wrought-iron brackets having vertical adjustments at intervals of 24 inches, on which platforms are supported.

To assist the drying of the paint and varnish, the shops are heated on the "Stanlock" system, and the temperature can be raised to 60 degrees F. when the outside temperature is down to 30 degrees.

WHEEL AND TIRE TURNING

In some cases chilled cast-iron wheels have been used for tram cars, but practically all those in Great Britain are now fitted with steel tires containing carbon .68 to .70 per cent., manganese .80 per cent. and silicon

.20 per cent., which is a very hard material, and will run from 50,000 to 60,000 miles before being worn out, though the tires will need returning three or four times during this period.

When first fitted on the wheel bodies, the tires are about 2½ inches thick, but can be used until they are only 1 to 1⅛ inches thick.

The turning of the insides of the tires to fit on the wheel bodies is usually done on a vertical boring mill using two tools.

A mill of this type, as used at Leeds, Birmingham and other places, is shown in Fig. 7, and two specially heavy mills, designed to the instructions and requirements of the London County Council Tramways Department for this purpose, are illustrated in Fig. 13.

In addition to boring the tires, this type of machine is used for general repair work, turning gear wheels, etc.

When the tires are worn out, they are split by an automatic hack saw and replaced by new, the wheel bodies being used over again.

A simple but effective system for putting new tires on the wheel centers is shown in Fig. 8.

After turning to size, the tires are heated equally all around by a ring of gas jets (which can be turned out of the way when not in use), and the wheel bodies, either on or off their axles, are lifted and placed in position by the overhead crane. The lowering of the displacement tank visible between the wheel pits forces the water up the centre of the pit, cooling the tire equally all round and causing it to shrink tightly on the wheel body.

In some cases the tires are afterwards secured by pins or riveting over the edge; but the experience in Birmingham does not show this to be necessary, as they rely upon the

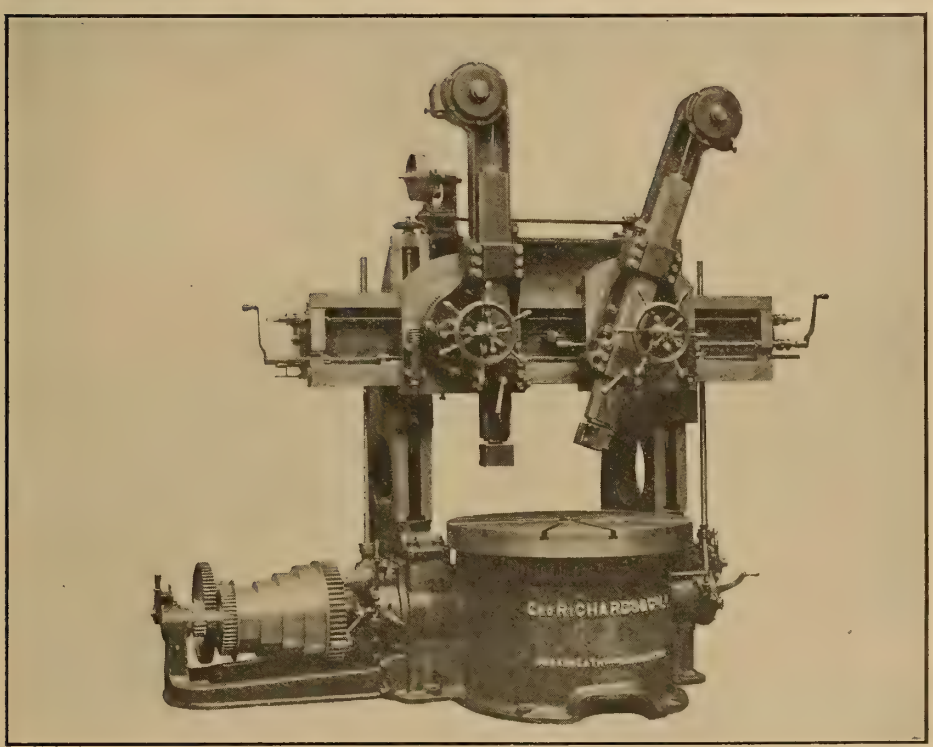


FIG. 7.—BORING MILL FOR TRAMWAYS, MADE BY GEO. RICHARDS & CO., LTD., BROADHEATH

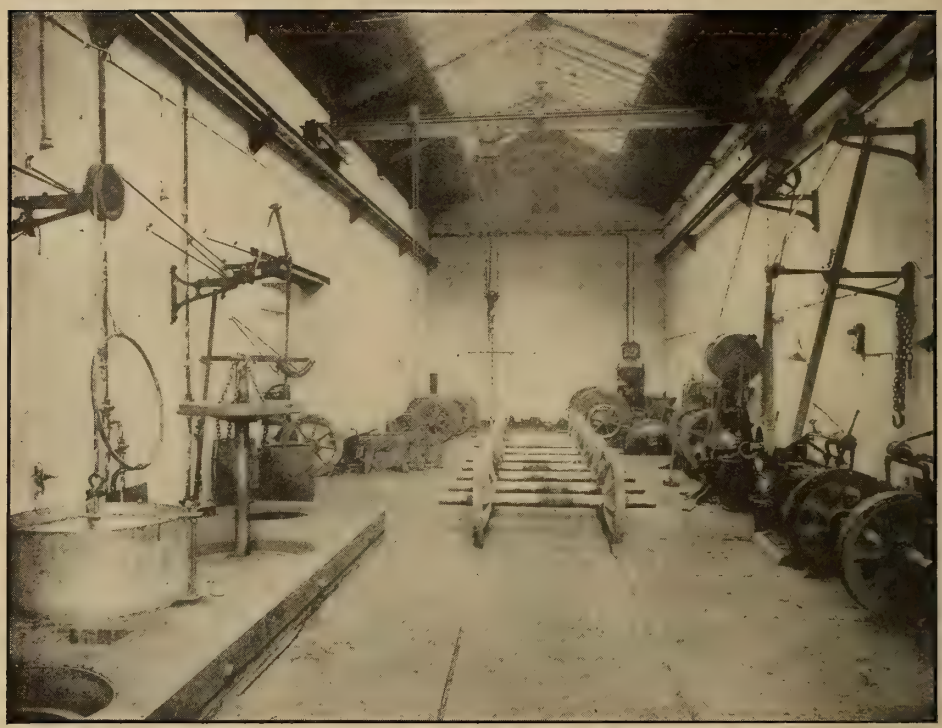


FIG. 8.—BIRMINGHAM WHEEL SHOP, SHOWING TIRE-SHRINKING TANKS

shrinkage only, and have not had any loose tires on the whole of the service.

At the far end of the wheel shop shown in Fig. 8 are two special motor-driven lathes for re-turning tires when they are worn.

The wear on the tread and flange varies; but is often on one side of the flange, as shown in Fig. 9, and to

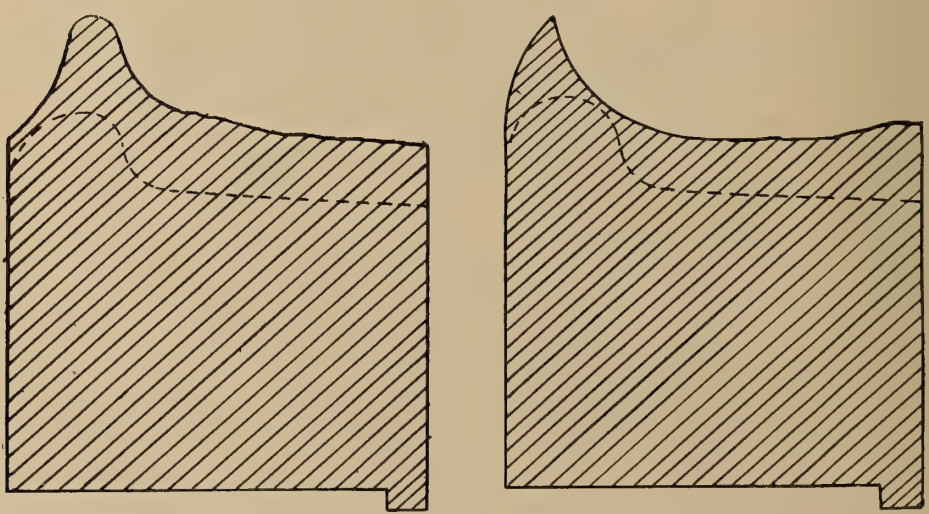


FIG. 9.—SECTIONS OF WORN TIRES, SHOWING AMOUNT TO BE TURNED OFF TO RENEW THE FLANGES

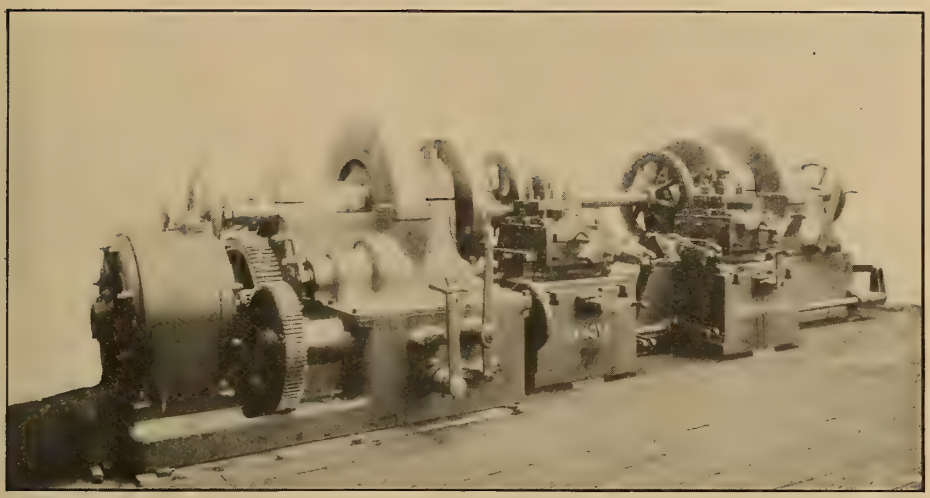


FIG. 10.—TIRE-TURNING LATHE MADE BY TANGYE, LTD., BIRMINGHAM

turn these to the correct shape again a considerable amount of material must be removed.

Owing to the hard steel used, which is made even harder on the skin by the constant rolling on the tram lines and the friction of the brakes, an ordinary wheel lathe cannot turn these tires in a reasonable time, taking as long as eight to ten hours to turn a pair of wheels even when using the best high-speed steel, the "chatter," due to want of rigidity in the lathe, causing the tools to quickly lose their cutting edge.

To overcome this difficulty and meet the requirements of the rolling stock, superintendent of the London County Council Tramways, Messrs. Tangyes, Ltd., of Birming-

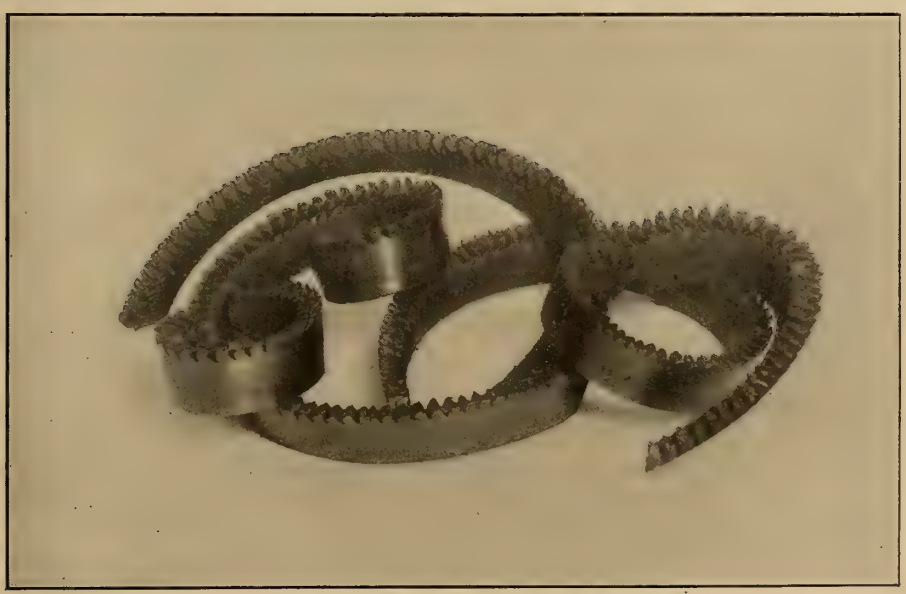


FIG. 11.—CUTTINGS FROM TIRE-TURNING LATHE

ham, designed the lathe shown in Fig. 10, which will take a cut on both tires at one time of ⅜ to ½ inch deep by ⅛ inch traverse at a speed of 25 to 30 feet per minute, and could be run at even higher speeds if suitable steel tools were available. For this duty a motor of about 40 horse-power is necessary, and the average output is six pairs of wheels per day.

A photograph of cuttings from one of these lathes is shown in Fig. 11.

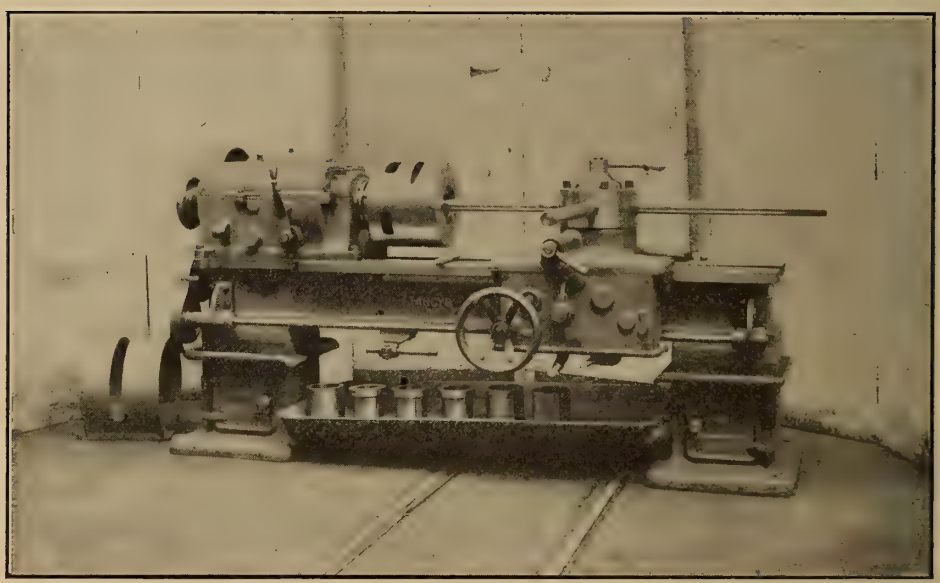


FIG. 12.—BORING LATHE FOR AXLE BEARINGS, MADE BY TANGYE, LTD., FOR THE L. C. C. TRAMWAYS

These were ⅜ inch deep by ⅛ inch traverse at a speed of about 35 feet per minute, and took 30 horsepower to drive the lathe when two tools were cutting at one time. A comparison with the cuttings illustrated in Mr. H. H. Suplee's paper before the Institution of Mechanical Engineers at Leeds in 1903 will show that considerable improvement has been made in high-speed steel tools and the machinery for using them during the last few years.

The pressure on each tool when doing the heaviest work was calculated at 8 to 10 tons, and it was not considered advisable to put such a strain as this involved upon ordinary centres; the axles were, therefore, carried by split conical bushes held in heavy sliding barrels at each end, which ensured the tires being turned true with the bearings, avoided any risk of throwing the wheels and axles out of the lathe, and prevented the axle being bent by supporting it close to the wheel boss; the sliding barrels are moved in or out by screws and large capstan hand wheels, which enable the wheels and axle to be placed in the lathe or removed very quickly.

The axles do not need replacement so often as tires, and are turned in the standard type of high-speed lathe.

The axle bearings are usually of gun-metal or lined with a special white metal. The machine shown in Fig. 12 is specially arranged for boring these to standard size. It has chucks and bushes to take any standard size of bearing, and each of the four boring bars, shown in the capstan rest, carries a standard size bor-

ing tool, finishing and facing cutters.

By swinging a selected bar into position, any ordinary size of bearing may be bored and faced without the trouble of fixing or resetting the boring tools.

MACHINE SHOPS

These are usually motor-driven and fitted with standard types of lathes, drilling machines, etc. Fig. 13 shows a part of the London County Council machine shop, which is 143 feet long by 43 feet wide and is equipped with a 3-ton, 3-motor overhead traveling crane; this covers the whole length of the shop, travels at speeds up to 200 feet per minute, and transfers heavy work quickly from one machine to another.

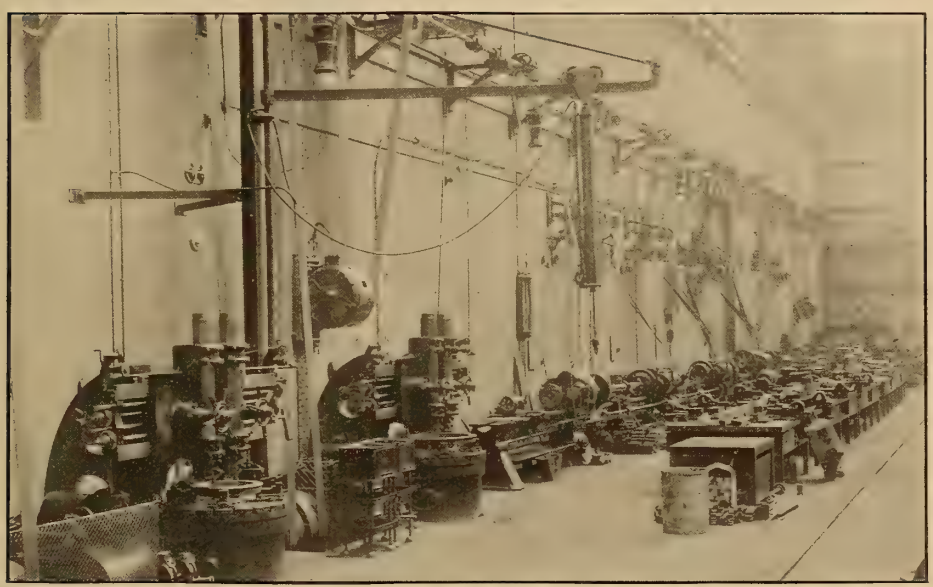


FIG. 13.—LONDON COUNTY COUNCIL MACHINE SHOP

In this shop a set of machines are specially arranged for machining magnetic brake-shoes, of which large numbers are required. The soft steel bars, when received from the rolling mills, are first cut to length by power hack saws and then placed in a jig on the table of the special milling machine shown in Fig. 14, where they have a "register" about 18 inches wide by 3-16 inch deep cut in them.

The jig will carry forty-eight bars at one setting, and the output of the bars is about sixty per hour. The cutter carries sixteen tools, which run at a speed of 60 feet per minute, with a table feed of 3½ to 4 inches per minute. The machine absorbs about 20 horse-power when doing this work and gives a very smooth finish to the surface of the blocks.

Another machine is provided with four spindles for drilling and tapping two ¾-inch holes in the shoes; these are carried in a jig and the two holes drilled at one time; then the jig is moved forward to the other two spindles, which tap the holes simultaneously.

In connection with the machine shop a tool room has been found necessary for grinding and repairing small tools, keeping standard gauges, jigs, drills, etc., and fully repays the small expense involved in keeping it in order.

WOODWORKING SHOP

Although the tram cars are bought complete from outside manufacturers, a considerable amount of wood work

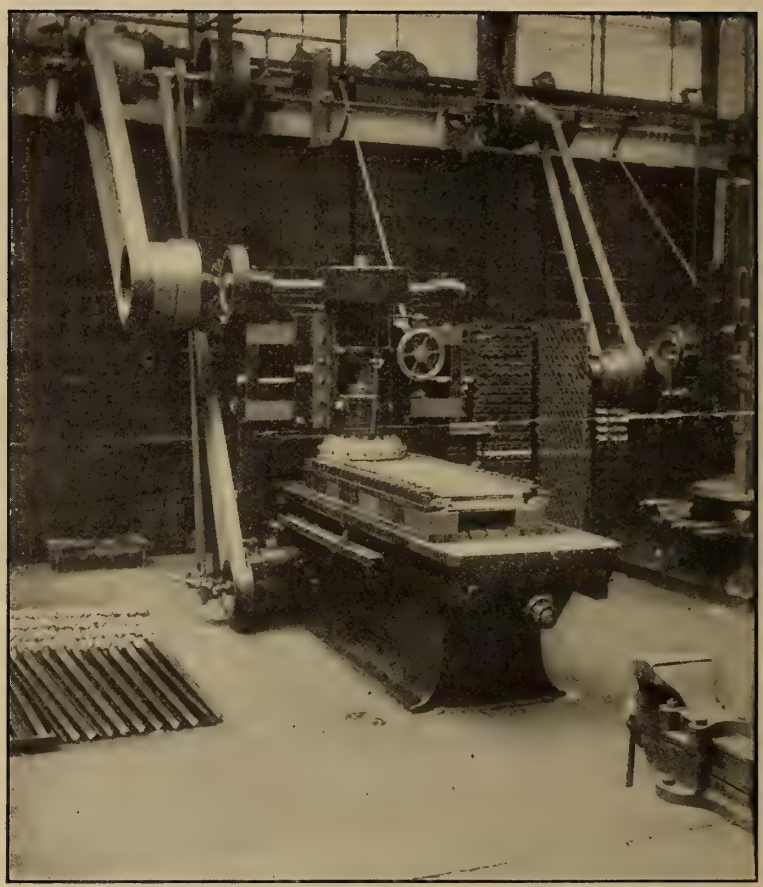


FIG. 14.—MILLING MACHINE FOR BRAKE-SHOES AT THE LONDON COUNTY COUNCIL TRAMWAY WORKS

is necessary for repairs, etc., and a complete equipment of woodworking machinery is generally provided, which is also used for making snow ploughs, truck bodies for store vans, and similar special work.

At the Birmingham shop, shown in Fig. 15, an ingenious jig has been designed for making the open type of wooden seat with three or four slots cut in one piece of wood at the same time; this is done quickly on the moulding machine by unskilled labour without any risk of injury to fingers, etc.

At Leeds the plant is also used for making the bodies of motor cars belonging to the corporation, which, to the number of seven or eight, are under the care and control of the tramway department. These cars are used by the general manager and his staff for inspection purposes, but are also at the service of the different committees and departmental officers of the Leeds corporation when on official business, each department sending a requisition for such cars as they require and being charged a suitable price for their use.

ELECTRICAL SHOP

To deal with the large amount of electrical work, a separate shop is provided and fitted with complete testing apparatus for motors which, when repaired, are generally tested with 20 to 25 per cent. overload for

FIG. 15.—TRAMWAY WOODWORKING SHOP OF THE BIRMINGHAM CORPORATION

a period of four or five hours. A separate shop, or section, is also arranged for armature and coil winding with suitable winding machinery, grinding machines for commutators, testing apparatus, vacuum drying and impregnating plant, etc.

A smithy, with smith's hearths, pneumatic hammer, electrically-driven blowers, etc., and a tinsmith's shop for re-metaling bearings and general sheet-metal and plumbing work, are provided in most large works.

Suitable foremen's and other offices, time-clocks, men's mess rooms, etc., are provided, and the arrangements and management generally will be found fully equal to any of the best modern workshops.

In addition to the ordinary repairs, the works are generally responsible for the up-keep of the motor tower wagons, for examining and repairing trolley wires, and make the woodwork and erect the stores vans for carrying goods between the different

FIG. 16.—SPECIAL RAIL-GRINDING CAR OF THE TRAMWAY DEPARTMENT, BIRMINGHAM

The stores arrangements are usually very complete and carefully arranged, to secure the maximum of economy and handiness.

A school has been found necessary in the works or at one of the depots for training the car drivers before they are allowed to take charge of a car on the road. Here they have to pass medical inspection for eyesight, etc., and are taught what to do in cases of accident, how to deal with a broken trolley wire, or to lift the car by jacks if it becomes derailed from any cause.

depots. These vans are fitted with the standard electric driving gear, wheels, etc., and in some cases have a jib crane inside with blocks, which can be swung far enough outside the doors to pick up heavy articles from the floor and deposit them in the van.

A special car, shown in Fig. 16, was made at the Birmingham corporation works for grinding the corrugations out of the tram rails.

The grinding wheels are made of carborundum, driven at a high speed from a 30 horse-power standard motor inside the car, whilst the latter is

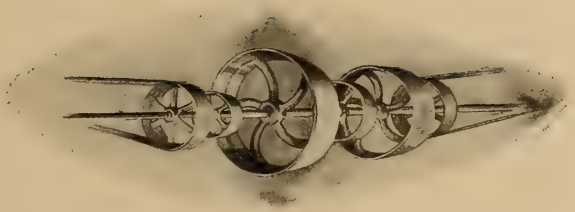
slowly moved to and fro over the corrugated surface. When the wheels have removed the ridges, carborundum blocks mounted on the car are slowly traversed across the rail surface to remove any slight inequalities that may have been left, and thus ensure perfectly smooth rails. Owing to the slow speed at which the car moves when doing this work, it was necessary to couple the main driving wheels to secure sufficient adhesion.

The arrangement of plough frame in front of the car meets the usual requirements of British weather, but at the Leeds repair works a special car has been built for snow removal; it is fitted with brushes placed diagonally across the car to sweep the snow to one side of the track, but as ordinary bristles soon become clogged, the brushes (which are rotated by a powerful electric motor carried in the car) have the bristles replaced by long canes, ¼ to 5-16 inch diameter, which do not clog, will last a considerable time, and can be quickly and cheaply replaced.

SAND-DRYING MACHINERY

In several repair shops special machinery has been arranged for drying the sand used for brake purposes.

This consists of a slowly-rotating drum heated by fires underneath, into which the sand is delivered at one end by elevators. Here it is kept constantly in motion and finally delivered at the opposite end to suitable chutes for packing into bags of convenient size for handling and carrying on the cars.



STRENGTHENING OF RAILWAY BRIDGES IN AMERICA

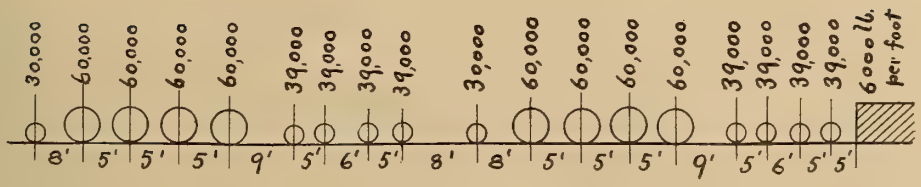
By George Sherwood Hodgins

IT is a trite saying that a chain is only as strong as its weakest link, and in a certain sense the principle involved is true of railway bridges. The increase in railway traffic which has taken place in the last ten or fifteen years has, broadly speaking, been gradual; but the increase in weight of locomotives and cars, although gradual in a sense, might be represented on a diagram as a series of steps. This is owing to the persistence of a type during its period of usefulness. One style of locomotive or car does not abruptly succeed another. After the original type has been in service for some time a heavier type is introduced, and both are used together for a time, then the lighter form is withdrawn, and a still heavier type subsequently makes its appearance. The diagrammatic representation of this method of procedure might even appear like the overlapping of shingles on a roof, but the net result is that the increase of the size and weight of the rolling stock has all along been proportional to the growth of traffic.

In the early days of railway construction in America it was natural that the wooden trestle should have been the first form of bridge. Such bridges were often replaced by embankments, as the lowering of grades or the widening of adjacent cuts provided material for the work. These wooden bridges were usually built by practical men, who relied on more or less empirical methods, evolved from their own experience. Whipple, in 1847, applied the first really scientific method of calculating the stresses in bridge members, and about 1874 steel first made its appearance in bridge work.

Wooden bridges were, in many instances, capable of being strengthened; that is, their original members could be reinforced. Steel bridges with riveted trusses, generally used for spans of 100 to 180 feet, were also capable of being reinforced by additional plates and structural shapes, riveted to existing members. Pin-connected truss bridges, used for spans of over 180 feet, did not lend themselves to reinforcing, and, as a rule, had to be rebuilt. Plate girder bridges were not generally reinforced, as it was often possible to transform bridges having two plate girders into bridges having four similar plate girders by the addition of two girders derived from a bridge which was replaced by a new one.

One of the most striking features of the work of bridge renewals which has been carried out, one might almost say as silently as it has been steadily proceeded with on practically all the railways of the country, is that no bridge has been taken down because it had become too weak for the loads it had been designed to bear. The increase of traffic introduced new conditions; but in no case, as far as the writer can learn, was an approach to the danger point permitted, but ample provision was made with an intelligent eye to future needs. This feature of the difficult and costly work of bridge reconstruction redounds alike to the credit of railroad bridge engineers and their staffs of assistants and inspectors. The arduous character of the work resulted from the fact that the traffic of the road was not only not sus-

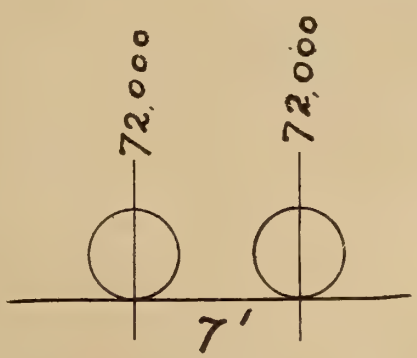


THE COOPER E-60 LOADING FOR BRIDGES

pended, but was not seriously interrupted at a time when the increase of business had indicated that bridge renewals were expedient. It was possible here and there to build the new bridge beside the existing one and to slightly deflect the alignment of the track; but in the vast majority of cases the track was supported on false work, the old bridge taken down, and the new one built up in its place with practically little or no delay to trains or the shifting of the rails from their original position.

In meeting the new conditions incident to greater traffic, the heavier rolling stock used augmented the effects produced on the bridge by a moving train. Imperfection of locomotive balance, flat wheels on cars, the centrifugal force on curves and the vibrations which always accompany a moving train, were greater than formerly. There was, also, the increased horizontal stresses in the bridge floor system caused by the greater tractive power of the heavier locomotives or the powerful braking of a rapidly moving train. Floor beams sufficiently strong to sustain in safety the vertical load had to be designed so as to resist successfully the now greater longitudinal thrust, which is the tendency of a heavy pulling locomotive to push the track behind it. This and the increased axle load comes directly on the floor system. Impact stresses, brought into play under new conditions, were more severe than formerly. The effect of a train at high speed passing over a bridge is supposed to approximate to that of a suddenly applied load. As a matter of fact, it must necessarily fall somewhat short of the theoretical effect of an instantaneous load, as the train occupies some period of time in moving over a given distance, no matter how fast it advances. The proper allowance for the effect of a train which rushes out at high velocity on to a steel structure constitutes one of the most intricate problems which confronts the bridge engineer.

Another and difficult problem in bridge design relates to the live load. The designer is aware of the live loads prevailing at the time the new bridge has to be built, but he must intelligently anticipate the live loads of the future. The dead load, as defined by bridge engineers, consists of the weight of the structure, together with the tracks and other supported material. The live load, however, has been subject to variation in the past and has steadily advanced. The crux of the question for the engineer lies in estimating closely the probable increase in the future, so that the bridge shall be safe and serviceable for a considerable period of time. The rebuilding



SPECIAL LOAD DIAGRAM FOR RAILWAY BRIDGES

WOODEN TRESTLE BRIDGE ON THE ESQUIMALT & NANAIMO RAILWAY, IN BRITISH COLUMBIA

of bridges is a costly item, and repeated renewal is out of the question. In all this undue weight must be guarded against as causing needless expense at the time the bridge is built.

There are many types of locomotives, and their wheel arrangements present a great variety of groupings, from the Consolidation engine, for freight service, to the Atlantic and Pacific types, for passengers, up to the recently-built Baldwin-Mallet compound of the 4-4-6-2 type for the Atchison, Topeka & Santa Fé. This engine has a total weight of 376,450 pounds, 286,000 of which are borne by the driving wheels, giving approximately a driving axle load of 53,600. The problem of determining

STEEL-ARCH BRIDGE OVER THE NIAGARA RIVER, GRAND TRUNK RAILWAY SYSTEM

a suitable live load would be much simplified if there was a settled type of heaviest engine. This does not exist, and the conception of an ideal locomotive for bridge-designing purposes is somewhat similar to that which came before the famous old anatomist Wolff, who felt impelled to write a treatise on the choice of typical examples of human viscera for representation in his work, upon which Darwin commented by saying

VICTORIA TUBULAR BRIDGE AT MONTREAL, QUEBEC, ON THE LINE OF THE GRAND TRUNK RAILWAY

VICTORIA JUBILEE BRIDGE AT MONTREAL, REPLACING FORMER TUBULAR BRIDGE

that "a discussion of the beau-ideal of the liver, lungs, kidneys, etc., as of the human face divine, sounds strange in our ears." The beau-ideal locomotive is, for the bridge engineer, a type which necessarily exists as an abstraction.

Theodore Cooper, the eminent engineer, in his general specifications for steel railroad bridges and viaducts, has at last brought the ideal locomotive down to paper, and his system of standard train loadings is now generally followed. On one

WOODEN BRIDGE, SHOWING ORIGINAL SUPPORTS, ALSO SUPPORTING MEMBERS ADDED WHEN BRIDGE WAS STRENGTHENED, AND STEEL ARCH BESIDE WOODEN STRUCTURE

prominent railroad (the West Shore) what is known as Cooper's E — 60 diagram has been used for bridge renewals, and on that road the live load for each track has been defined as two consolidation locomotives coupled and followed by a uniform load, as shown on the diagram.

A special load of 144,000 pounds equally distributed on a pair of axles spaced 7 feet centre is used in all cases where the stresses produced thereby would exceed the stresses due to the E — 60 loading.

tower was 245 feet above the water. The lower chord sustained a roadway for foot passengers and vehicles.

The steel structure which replaced the suspension bridge is a solid riveted steel arch, more technically called an open spandrel arch bridge. The top chord is horizontal, and the lower chord, which forms the arch, is a parabola. The arch has a clear span of 550 feet, and the rail level is 226 feet above the river. The bridge is composed of two trusses, which are

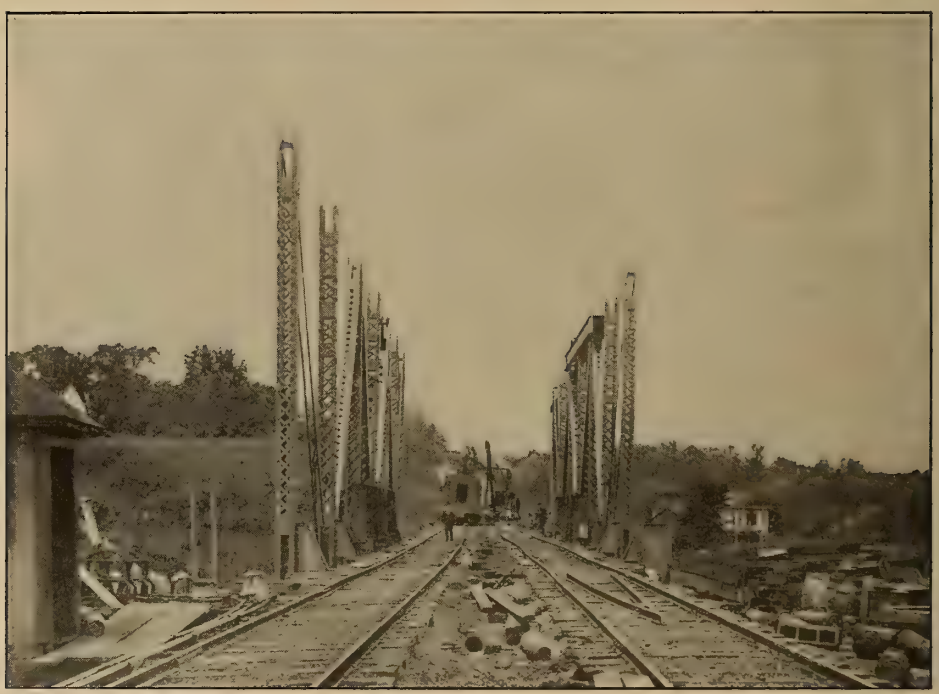
BRIDGE NO. 278, OVER ERIE CANAL, SHOWING NEW STRUCTURE IN COURSE OF ERECTION

One of the most remarkable changes in bridge structures brought about by the gradual increase in traffic was the substitution of a double-track steel arch bridge for the famous old single-track suspension bridge over the Niagara River on the line of the Grand Trunk Railway. The suspension bridge was opened for traffic in 1855, and was in continuous use from that time until 1897, a period of forty-two years. It was built by the late John A. Roebling, was 821 feet 4 inches long between the centres of the towers, and was carried by four 10-inch steel cables. The

inclined toward each other with a batter of 1 in 10. The top chords are 30 feet apart, and the spread of the centres of the abutments is 54 feet. This offers a very effective resistance to wind stresses. The abutments are built with faces inclined at 45 degrees, and upon each of them rests a heavy casting. The end of each arch truss carries a foot which is curved to a radius of 42 inches. The convexity of this curve is outward or away from the arch. The foot fits into a corresponding hollow in the abutment casting, and between the two a series of rollers is inter-

posed. The rise and fall of the arch, due to variation of temperatures or under load, is thus allowed for in hinge-like arrangement on the abutments.

This bridge was built up around the old one, a truss being placed on each side of the suspension bridge, which was itself a hollow box 25 feet wide at the top and 18 feet deep. The shore spans were built on false work in the usual way, and of each half span as the half arches springing from each shore met high in the air above the centre of the stream. A slight movement of the toggle was sufficient to raise and lower the chords of the arch, so that perfect adjustment was easily assured. The horizontal length of the toggle was shortened or increased by the movement of a cast-iron nut, turned by six levers, each 11 feet long.



BRIDGE NO. 278, WEST SHORE RAILROAD, OVER ERIE CANAL, LOOKING ALONG THE TRACKS

are Pratt trusses. To the upper end of the first post, which stands vertically over the abutments, the top chords of the Pratt trusses were fastened to one end of a toggle, and the other end of the toggle was suitably anchored to the solid rock. By means of the toggle the first post over the hinge on the abutment could be moved either way out or perpendicular. The arch, with the panels above it, was thus built out piece by piece over the stream, and the anchorage finally sustained the weight

In a memoir published in 1856, Mr. Roebling, when writing of the suspension bridge, says: "The constant pressure on each tower is 500 tons; this gives a weight of 200 tons for suspension bridge." The weight of the steel bridge is about 3,600 tons. Its length is 550 feet, with two shore spans each 115 feet long, making a total of 780 feet. The steel bridge is, therefore, about 41 feet 4 inches shorter than the suspension bridge; but it must be remembered that the steel bridge is 32 feet wide, and, like

Courtesy of the American Bridge Company

KINZUA VIADUCT, ON THE ERIE RAILROAD, SHOWING NEW BRIDGE AT LEFT-HAND SIDE OF PICTURE, TEMPORARY SPAN TO CARRY TRAFFIC WHILE WORK IS BEING DONE, AND OLD STRUCTURE OF LIGHTER FORM AT THE RIGHT OF THE PICTURE

its predecessor, has a carriage-way below the deck upon which the trains move. The cost of the suspension bridge was about $400,000. At the time it was built the weight of the locomotives then used did not exceed 35 tons, and a train of 200 tons was the exception. The steel arch bridge cost about $275,000, and is capable of easily sustaining modern loads with safety. The arch was designed by Mr. L. L. Buck, of New York, and the work was done by the Pennsylvania Steel Company. During the erection of this magnificent structure not a life was lost and the

BRIDGE NO. 570, WEST SHORE RAILROAD, OVER TONAWANDA CREEK, SHOWING FALSE WORK IN POSITION CARRYING TRACK

BRIDGE NO. 570, OVER TONAWANDA CREEK, SHOWING NEW TYPE OF BRIDGE AND THE CONCRETE TOPS TO STONE PIERS TO BRING THEM TO NEW LEVEL

LEHIGH & NEW ENGLAND RAILROAD BRIDGE AT PORTLAND, PA., SHOWING ONE NEW SPAN IN POSITION READY TO BE LOWERED INTO POSITION AS SOON AS OLD SPAN IS JACKED TO ONE SIDE

traffic of the railway was not seriously hampered. Each was a noble example of the bridge builder's art. The downward sweep of the suspension cables have been replaced by the upward curve of the arch, which stands where once hung probably the most widely-known international bridge in the world.

Another very important railway bridge renewal was the substitution of the double-track Victoria Jubilee Bridge, a through, Pratt truss, pin-connected structure for the old Victoria tubular bridge on the Grand Trunk Railway at Montreal. The tubular bridge was inaugurated in 1860 by the Prince of Wales, now King Edward VII., and was in its day one of the most famous bridges in the world. It was situated just below the Lachine rapids on the river St. Lawrence, and where it stands the river runs at the rate of 7 miles an hour. The engineers were Robert Stephenson and F. M. Ross. In certain particulars both old and new bridges are alike, as the new bridge stands on the piers which formerly supported the tube. The piers were made wider for the new bridge by having extensions built on the down-stream side. The width of the tubular bridge was 16 feet, while the Pratt truss bridge measures 31 feet 2 inches from centre to centre of main trusses.

The tubular bridge was replaced not because it was too weak to carry the weight imposed on it, but because it had become inadequate for modern requirements. The present bridge has two tracks, and the floor beams are extended out on each side so as to carry a vehicular roadway on each side. The length of the tubular bridge, 6,592 feet, with approaches each 1,276 feet long, gives a total of 9,144 feet from shore to shore. The number of spans are 25, and they are from 242 to 247 feet long in the clear, with a centre span of 330 feet. As the same piers were used in both cases, the new bridge has the same

number and length of spans, and the centre of old and new bridges is 60 feet above the water. The grade remains as formerly, 1 in 130 to the centre, from each shore.

The differences in the two bridges are significant of the times in which each was built. The tubes weighed 9,044 tons, while the new bridge weighs 22,000 tons. A glance at the two bridges almost instantly reveals the general advance in the art of bridge building which has taken place in the thirty-eight years during which the tubular bridge was in use. It carried a single line of railway track and cost about $7,000,000, while a bridge more than twice as heavy and of far greater capacity, and having a vehicle road on each side, was built for $2,000,000. Even adding the cost of the piers and other parts common to both structures, the total for the new one would still be far below the outlay for the original bridge. The work of substitution was done without impeding the railroad traffic. The Victoria Jubilee Bridge was opened in 1897.

Coming down to even more modern times, the West Shore Railroad authorities have very successfully carried on the work of bridge renewal during the years 1904-6. Two bridges, taken casually from the list of those rebuilt, may fairly be considered as typical examples. Bridge No. 278, over the Erie Canal near Fort Plain, consisted of a through, pin-connected Whipple truss bridge of two spans. One of these was 198 feet long and the other, over a highway, was 57 feet long. Each span consisted of two trusses, and each carried two tracks. This bridge of two spans was replaced by a through, pin-connected bridge of two spans, 201 and 56 feet long, respectively. The estimated weight of the old bridge was 308.2 tons, while the new bridge weighed 586.8 tons. The new bridge is, therefore, nearly twice as heavy as the old one.

Bridge No. 570, over Tonawanda

Courtesy of Pennsylvania Steel Company.

ORIGINAL BRIDGE NO. A-308-C, ON THE LEHIGH VALLEY RAILROAD, SHOWING OLD TRUSS

LEHIGH VALLEY RAILROAD BRIDGE OVER FALLS CREEK AT ITHACA, N. Y., SHOWING ONE NEW GIRDER AND METHOD OF PLACING IN POSITION. BUILT BY PENNSYLVANIA STEEL COMPANY

CENTRAL RAILROAD OF GEORGIA BRIDGE OVER THE TALLAPOOSA RIVER, NEAR STURDEVANT, ALA., SHOWING ONE NEW SPAN IN POSITION ON LEFT OF PICTURE. PENNSYLVANIA STEEL COMPANY, BUILDERS

Creek near Alabama, N. Y., originally consisted of the three spans each, a Pratt deck truss, pin-connected bridge, the two shore spans measuring 40 feet and the three centre spans each 92 feet 6 inches. The bridge is estimated to have weighed 228.4 tons. It was replaced by a deck-plate girder bridge with two spans 39 feet long and three spans 94 feet 7 inches long. This bridge weighed 226.93 tons. The change in the type of bridge required one abutment to be extended with new coping, and the pier had to be built up to the new level with reinforced concrete. The illustrations very clearly show the alteration of the piers.

The Erie Canal bridge was made 278.6 tons heavier than its predecessor, and being of the same type, the increase of weight is, roughly speaking, an index of its increased strength. A contrast is apparent in the second case. The bridge over the Tonawanda Creek was originally built for two tracks, while the new bridge, built to carry only one, is within one and a half tons as heavy. It is, therefore, fair to suppose that if the original bridge had been built for a single track the new structure would have been very nearly double the weight of the first. The design of the new bridge is unlike the old one, so that no reliable ratio between weight and strength exists. It is where a comparatively light design is replaced by a bridge of the same type composed of heavier members that the increase of weight may be said to approximate to strength.

A survey of eighteen rebuilt bridges between Rotterdam Jet and Buffalo, where the older structures have been replaced by similar types, and where it is fair to take the increase in weight of the new bridges as indicating the increase of strength, shows that these bridges, together, weighed about 2,292.25 tons, while the new structures weigh about 4,132.3 tons, or an increase of 1,840.05 tons in all. Thus the weight of the specified eighteen bridges has been increased about 80 per cent. If, however, the increase of weights of these bridges is worked out into a separate percentage for each bridge and an average of the percentages thus found be taken, the average of percentages for these eighteen bridges will show an increase of 78 per cent. Out of the fifty-eight bridges rebuilt on this portion of the West Shore these eighteen have been selected as the ones in which increase of weight most nearly approximates to increase of strength, and we find that, speaking generally, these bridges may be taken as a fairly accurate indication of the increase in the strength of practically all the new structures over the old.

The replacing of a bridge over the Delaware River on another important railroad practically bears out the conclusion just drawn. The old bridge was a double-track, through, pin-connected, Pratt truss bridge erected in 1891, four spans of 143 feet 9 inches and one span 144 feet long. The weight of this bridge was 776.5 tons. This structure was replaced in 1904 by five spans, forming a through, pin-connected, sub-divided Pratt truss bridge, each span 142 feet long from centre to centre of end pins. The bridge weighs 1,426 tons, making an increase of 650 tons. It is fair here, also, to take weight as an approximate measure of the increased strength of the new bridge, and in this case it has been increased nearly 84 per cent.

In the matter of bridge renewals the increase of bridge weight and bridge strength may not have been as gradual as that of rolling stock. Locomotives and cars wear out, are destroyed or become obsolete, and are replaced more rapidly than is possible with permanent structures. Nevertheless, there has been a general correspondence between the growth of railroad business and bridge renewals, and the cost of extensive bridge renewals constitutes one of the heaviest items of railroad expenditure.

MOUNTAIN AND RACK RAILWAYS

By Roman Abt

ABOUT one hundred years ago the first proposition was made to build what is now called a rack railway, this being an English idea, and thus emanating from the nation which has done so much to advance the development of railroading. It was in 1811 that the idea of transporting coal by means of a rack railroad occurred to John Blenkinsop, owner of the Middleton coal mines, near Leeds. He placed the work in the hands of Matthew Murray, of Leeds, and within a year the road was ready for service. This was a real rack railway, one rail having teeth cast upon one side, the rack teeth having rounded tops and engaging with a spur gear driven by the engine of the locomotive, and thus causing the propulsion of the train. Some interesting relics of this first rack railway may be seen at South Kensington, and also in the Germanic Museum at Munich.

At the time this railway was built it was believed that the friction between the rails and the driving wheels would be insufficient for the propulsion of the train, even at moderate grades. The experiments of Blakett and Hedley, however, showed that considerable loads could be drawn upon smooth rails by mere adhesion. Thus, while the Leeds rack railway continued in operation for twenty-five years, no similar railroads were constructed for a long time.

The next application was made in America, when Mr. Cathcart, of Indianapolis, made use of the rack for increasing the tractive effect of the railway between Madison and Indianapolis. In this case the rack rail was used to enable the haulage of heavy trains upon a grade of 5.9 per cent., the new departure being made in this case of laying the rack between the two rails. This road was operated until 1868, when the rack locomotives, which had been built by the Baldwin Locomotive Works, were replaced by powerful adhesion locomotives constructed by the same firm.

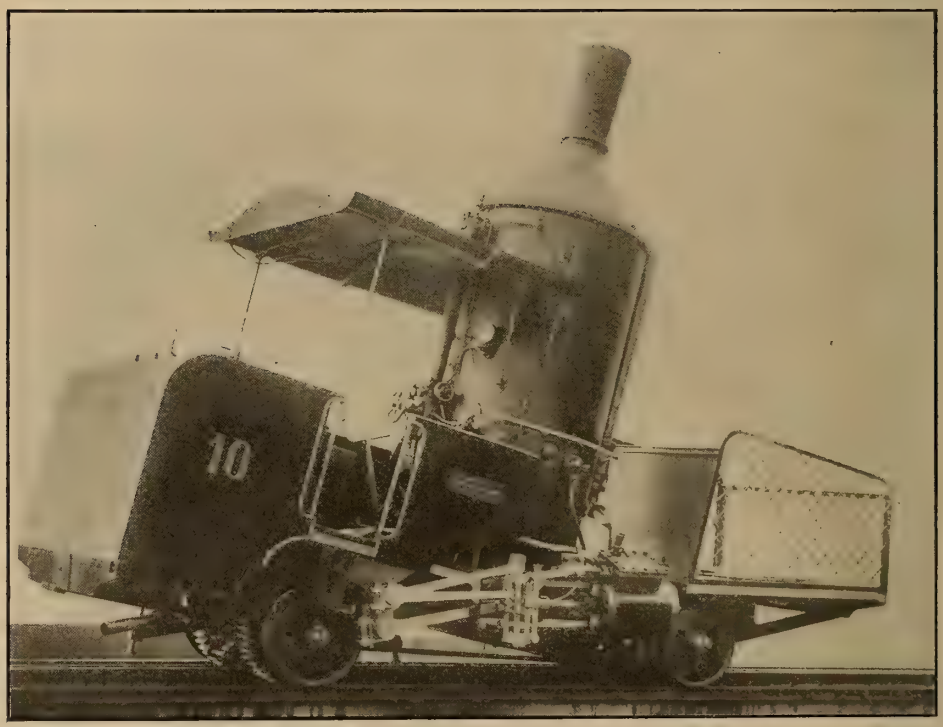
In 1866, however, another American, Sylvester Marsh, had succeeded in raising funds for the construction of a novel application of the rack and pinion to railway service. Originally the rack had been proposed for the hauling of ordinary loads on a railroad. This was then modified to permit the hauling of unusually heavy loads, but Marsh was the first to apply the rack for the object of overcoming excessively steep grades. Such a railway was naturally applicable only for passenger traffic, and not for the haulage of freight.

The first example of a railway built according to the ideas of Marsh appeared in the Mount Washington Railroad, in the White Mountains, in which case the maximum gradient was 37.7 per cent. In this installation a comparatively very efficient locomotive and very practical construction of rack was used, the latter being in the form of a ladder composed of a pair of angle bars, with pin teeth between them. The construction of the Mount Washington Railroad was the first example of a new form of line, namely, the tourist railway, a system developed afterwards by a Swiss engineer, Nicholas Riggenbach, who constructed the famous rack railway on the Rigi Mountain, near Lucerne, in Switzerland.

The track and rolling stock of the Rigi Railroad were modeled very closely after the American example, but in the construction of the railway it was found possible to secure the

comparatively low maximum grade of 25 per cent.

This rack railway was followed by many others in Switzerland, Austria-Hungary and Germany; but as most of them met with very moderate financial success, the work gradually diminished. One reason for this lay in the fact that it was found possible to construct railways working on the adhesion principle upon gradients up to 7 per cent., and a number of such roads of minor importance were built.



EARLY TYPE OF LOCOMOTIVE USED ON THE RIGI RAILWAY

It was found, however, that grades of 2.5 to 3 per cent. could not well be exceeded without largely increasing the operating expenses and diminishing the safety.

These experiences with mountain roads led to various expedients to overcome the obstacles which mountain ranges opposed to railway traffic, and in many cases the routes were carried around by considerable distances, involving numerous curves in the system to escape the steep grades. These efforts are apparent in the numerous tunnels, viaducts, bridges, etc., structures which greatly increase the expense of construction and add to the burden of operation. In some cases the building of such railways has been possible only by the aid of government subsidies, while many mountainous regions are yet without railway transport of any kind.

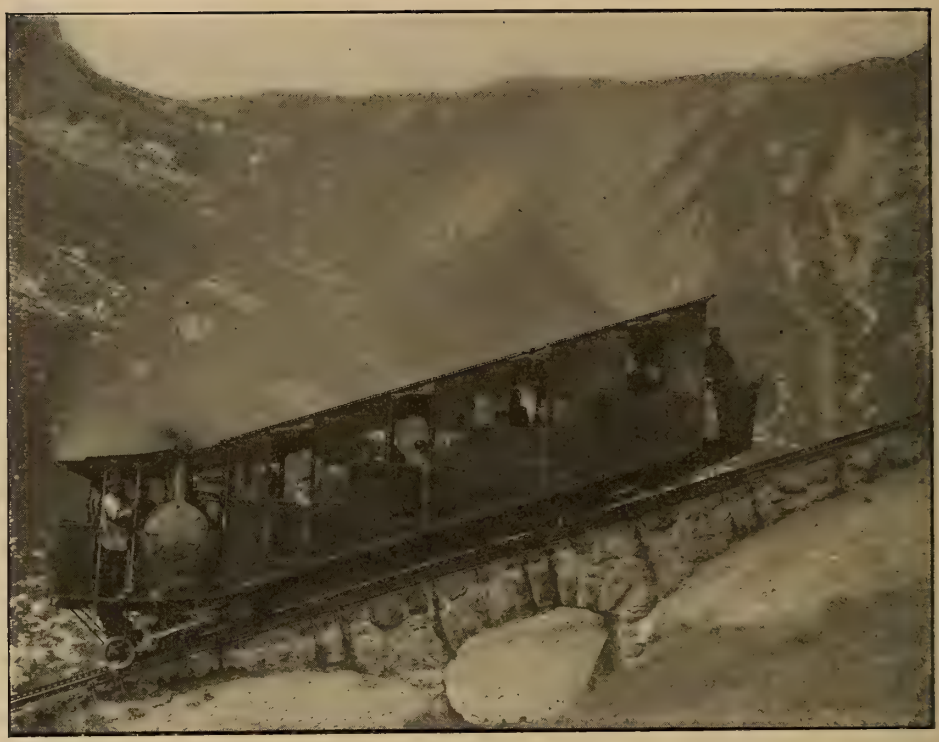
In order to overcome these difficulties the problem of mountain railways was attacked by M. Roman Abt, a pupil of Riggenbach. To him it appeared possible to apply a suitable combination system which should render it practicable to haul ordinary loads not only upon moderate gradients, but over ascents of 5 to 7 per cent. directly, thus reducing the length of the line to one-half or even one-third that which would otherwise be necessary by the exclusive use of the adhesion system. Such a system

A STEEP INCLINE ON THE MOUNT PILATUS ROAD, BUILT BY COL. LOCHER

would not only enable a much shorter route to be adopted, but would also avoid much of the expensive construction otherwise necessary.

The locomotive in the Abt system operates by adhesion at all times, just like an ordinary locomotive. Where the grade exceeds 2.5 per cent., how-

COMBINATION ADHESION RACK LOCOMOTIVE USED ON THE KARANSEBES-HATSZEG RAILWAY IN HUNGARY



AN EXAMPLE OF A RACK LOCOMOTIVE AND PASSENGER CAR FORMING ONE UNIT. MOUNT PILATUS ROAD ENGINE

THE ABT-TYPE RAILWAY ON PIKE'S PEAK, COLORADO

ever, pinions upon the engine engage with multiple racks, the gearing thus assisting the action of the driving wheels upon the track. As soon as the steeper gradient is surmounted, the rack is discontinued and the locomotive operates by adhesion only until the next ridge is approached. The action is not dissimilar to the old-time plan of having an extra pair of horses to assist the stage coach upon steep portions of the road, except that the modern engine always carries its reserve with it.

The above described system was first practically applied by Geheimrat A. Schneider in the construction of the Harz Railway, in which he was extraordinarily successful. This road working alternately on the adhesion and rack-and-pinion system, attracted engineers and students from all parts of the world, and at the present time similar lines are in use in many parts of the world.

At the present time the general tractive power of heavy adhesion locomotives ranges between 18,000 to 22,000 pounds, while some of the modern rack and adhesion engines have a tractive capacity of 40,000 to 44,000 pounds. A combination locomotive of this kind, used upon the Karansebes-Hatszeg Railway, in Hungary, is shown in the illustration.

A rack mountain railway, which may be considered as a successor to the Rigi Railroad, is the road to the summit of Mount Pilatus, near Lucerne, in Switzerland. This was designed by Col. Locher, of Zurich, who employed the very ingenious method of a double rack having vertical teeth cut on each side, a pair of pinions on vertical axes being used. This road, views of which are shown, surmounts maximum grades of 48 per cent.

The Jungfrau Railway, built by Herr E. Strub, has the rack teeth cut into the head of a heavy rail of the Vignoles type, a plan which has been adopted in other instances.

At the present time there are about 150 rack railways in operation or building, with a total mileage of 932 miles. The most important of these is the Arica Railway, crossing the Andes to La Paz, in Bolivia. This crossing of the Cordilleras, built by Sir John Jackson, is about 250 miles in length, and has a total rack length of 22.33 miles. The maximum gradient is 6 per cent., and trains are hauled by locomotives of the Abt type over an altitude of 13,200 feet above the level of the sea. The ten-wheel engines used on this road were built by the Maschinenfabrik Esslingen, and the rack bars by Messrs. Cammell, Laird & Co., of Sheffield, and by the Union Company, of Dortmund.

The above road is the second instance of the crossing of the Andes by means of a rack railway. The construction of the first road was begun by Clark Brothers between Mendoza and Santa Rosa twenty years ago, and will be ready for use during the present year.

Among the roads operating with the Abt rack may be mentioned the railway to the summit of Pike's Peak, in Colorado. This has a length of nearly nine miles, with a maximum gradient of 25 per cent. and an average incline of 17 per cent. The general design of the engine is seen in the accompanying illustration.

BRITISH EXPRESS LOCOMOTIVES

By John Farquharson M'Intosh

THE principal and necessary characteristics of the modern express locomotive are great power, high speed and unfailing reliability in all weathers. This last feature is not the least important, for while it is something to take trains of 400 tons and upwards at speeds of 55 to 60 miles per hour, it is the doing of it regularly and punctually, in spite of bad weather, bad roads and many trifling delays, that makes it really a great feat.

Nothing has conduced so much to the improvement of the modern express engine as the introduction of the large boiler, and it is now recognized as the real measure of the power of the engine. Twenty years ago a heating surface of 1,200 square feet was considered large; to-day one of 2,000 to 2,400 is required. This increase in size is more noticeable in the firebox than in the boiler barrel, showing that there is a truer appreciation of the value of large grate area and firebox heating surface as compared with tube surface.

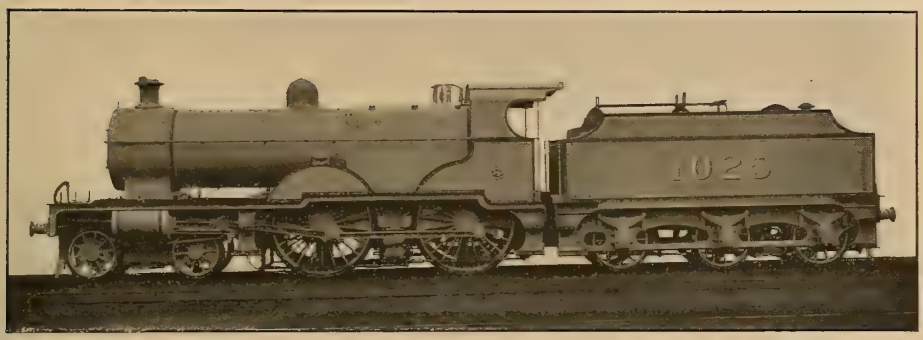
A minor feature of the express boiler which serves to indicate its growth in size during recent years is the large safety valve area now considered necessary. It is not so very long since two 2½-inch valves were considered sufficient; now some boilers have four safety valves 4 inches in diameter, which are all required.

This naturally brings us to the consideration of the working pressure, which must be high for the modern express engine. Two hundred pounds per square inch and even over that figure is now common, and anything less than 180 pounds will not do, unless where superheated steam is used.

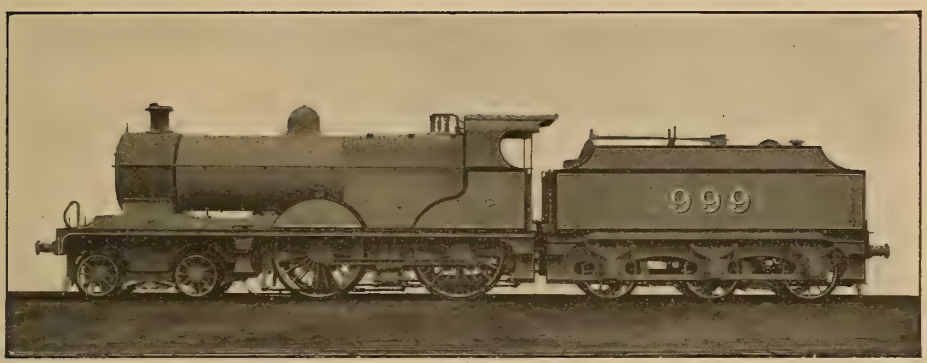
Locomotive boilers seldom have a higher factor of safety than 4½, but even this with these high pressures means a very heavy boiler and a fast life. The high pressures have compelled the re-introduction of the direct firebox roof stays, giving better circulation and saving weight; but the much increased wear and tear in the firebox is still an unsolved problem. Over 160 pounds pressure the stay heads are a continual worry, unless the new high-tensile bronze is used, while copper stays are lacking in strength. Steel tubes have come to stay, not because they are cheap and light, but because they are reliable; and perhaps experience may yet beget confidence in the same good qualities of the steel firebox.

Coming to the question of the size of cylinders for an express engine, the ruling gradient and its length must first be considered and the largest possible size adopted consistent with the boiler's steaming capacity. In general, the locomotive that has to do much hill-climbing must have large cylinders if the steam is to be used economically, and for the same reason smaller cylinders are preferable on the engine that does its work mainly at high speeds on a fairly level road.

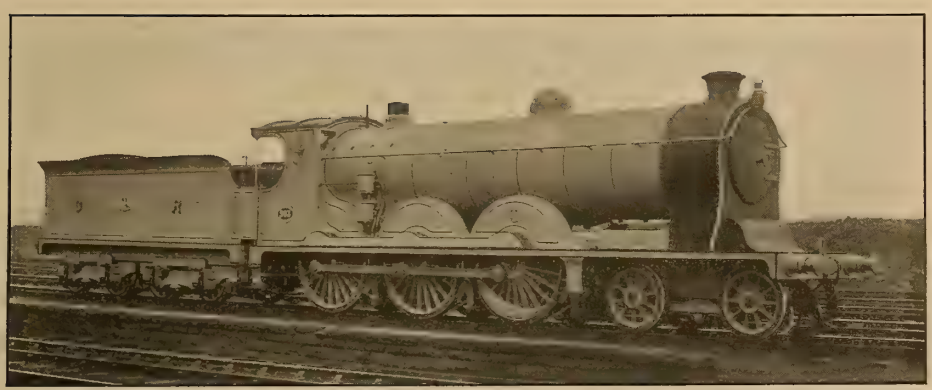
With inside cylinders, with the valves between, worked by a direct motion, the largest diameter obtainable is 19 inches. If a diameter of 19½ or 20 inches is adopted, then the valves must be placed on the top with the drawbacks of a rocking shaft and crossed rods, unless we use the Joy or Walschaert valve gear. Another



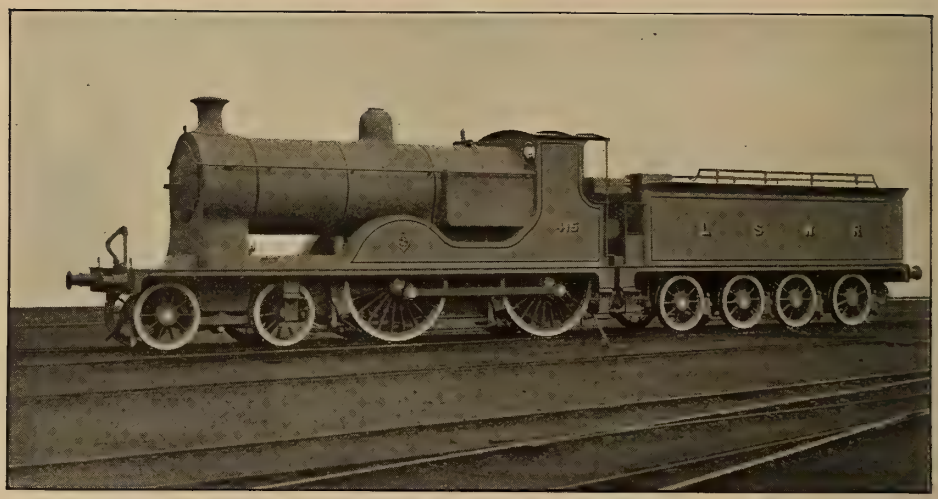
MIDLAND RAILWAY FOUR-CYLINDER COMPOUND ENGINE, 4-4-0 CLASS. TOTAL WEIGHT 105½ TONS
DERBY WORKS



MIDLAND RAILWAY EXPRESS ENGINE, 4-4-0 CLASS. TOTAL WEIGHT 103 TONS. DERBY WORKS



CALEDONIAN RAILWAY 4-6-0 CLASS EXPRESS ENGINE. WEIGHT 73 TONS. DESIGNED BY MR. MC INTOSH,
ST. ROLLOX WORKS

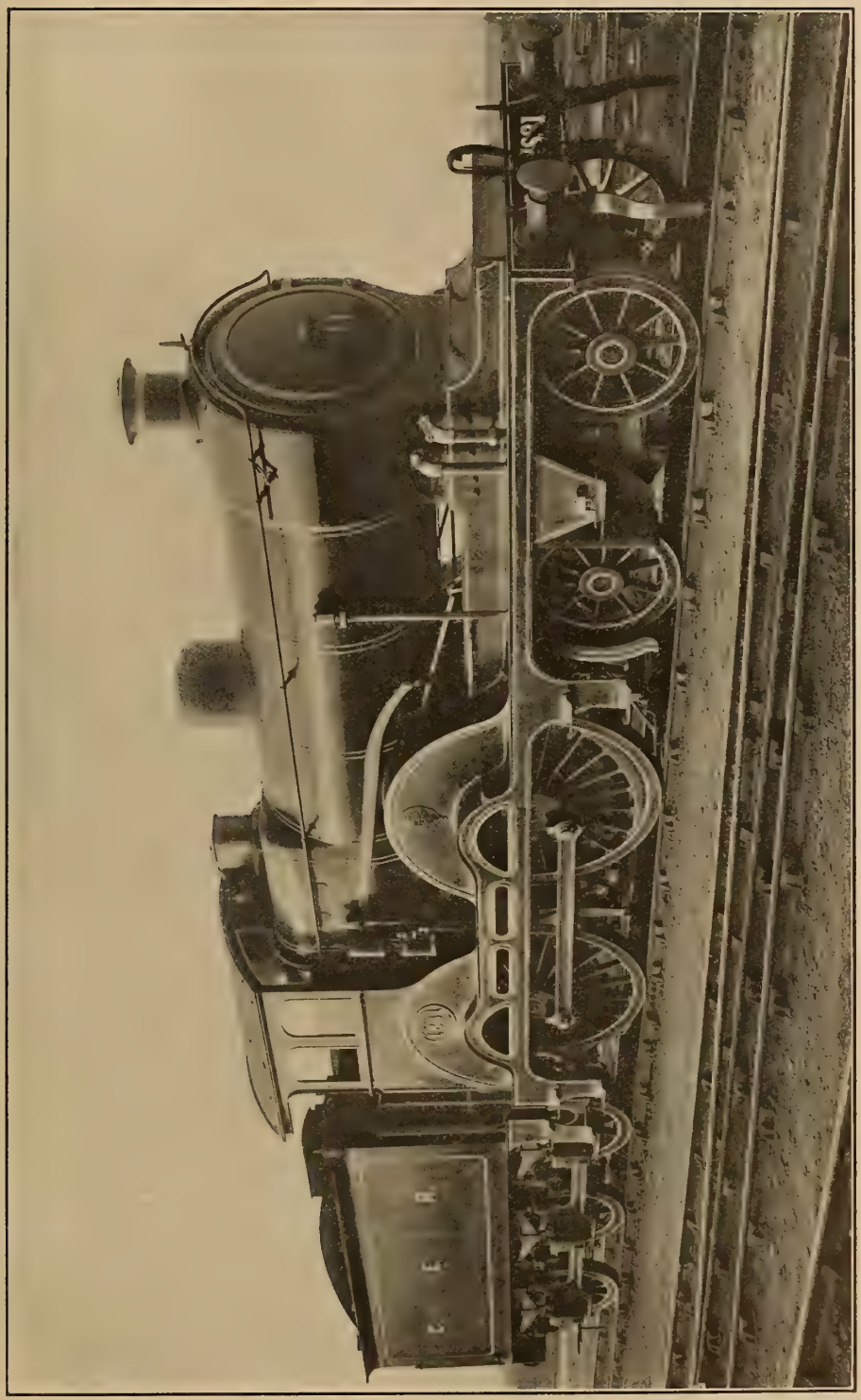


LONDON & SOUTHWESTERN 4-4-0 EXPRESS ENGINE, WITH FEED-WATER HEATER IN TENDER

method is to use piston valves with inside admission, in which case, while we must still retain the rocking shaft, we obtain open rods. Of course, piston or ordinary valves can be arranged below with a direct motion; but that means an inclined motion or inclined cylinders, resulting in bad valve setting, owing to the disturbing effect of the rise and fall of the driving axle on the springs.

That the moving parts of an express engine should be properly balanced, is admitted by all; but there are considerable differences of opinion in regard to the method. The most generally accepted principle is that one-half of the reciprocating and the whole of the revolving weights should be balanced, and to avoid inordinately large weights on the driving wheels the reciprocating balance weights may

EXPRESS PASSENGER ENGINE, 4-4-0 CLASS, NORTH EASTERN RAILWAY, DARLINGTON WORKS

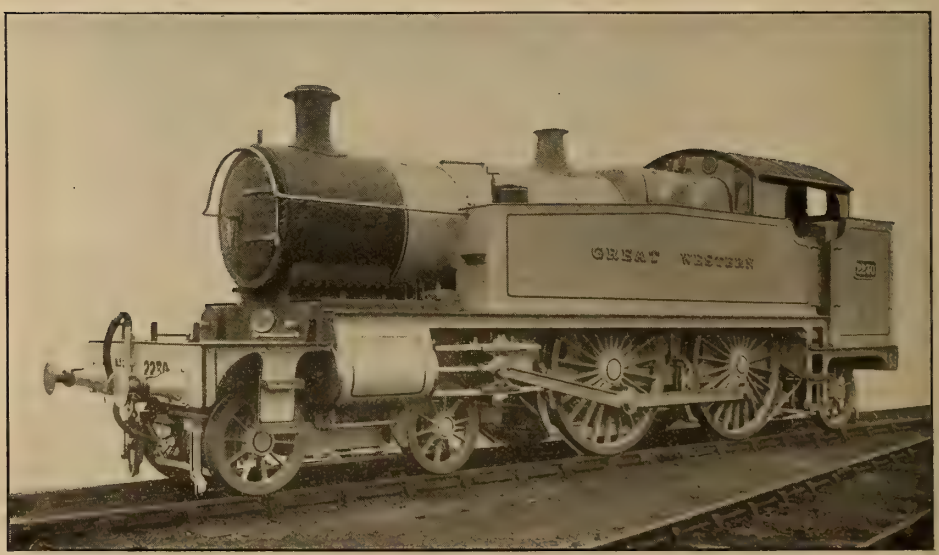


LATEST TYPE OF EXPRESS PASSENGER ENGINE, 4-4-0 CLASS, GREAT EASTERN RAILWAY

GREAT NORTHERN RAILWAY 4-4-2 EXPRESS ENGINE. DONCASTER WORKS

be distributed over all the coupled wheels. However much we may desire correct balancing, no one can state its value in pounds of coal per mile, or point to an accident clearly traceable to balancing unskilfully carried out; yet anyone who has stood on the side platform of an express engine running at 60 miles per hour and observed the speed of the moving parts could not fail to be impressed with the importance of balancing.

Of greater importance in the design of an express engine is the question of the dimensions of the bearings, for whatever its other good points may be, they are absolutely valueless if the engine gives trouble with heating. Liberal dimensions in this respect always pay, while minimum sizes, which save little in first



GREAT WESTERN 4-4-2 TANK ENGINE. SWINDON WORKS

CALEDONIAN RAILWAY 4-6-0 CLASS ENGINE FOR PASSENGER SERVICE. WEIGHT 64 TONS

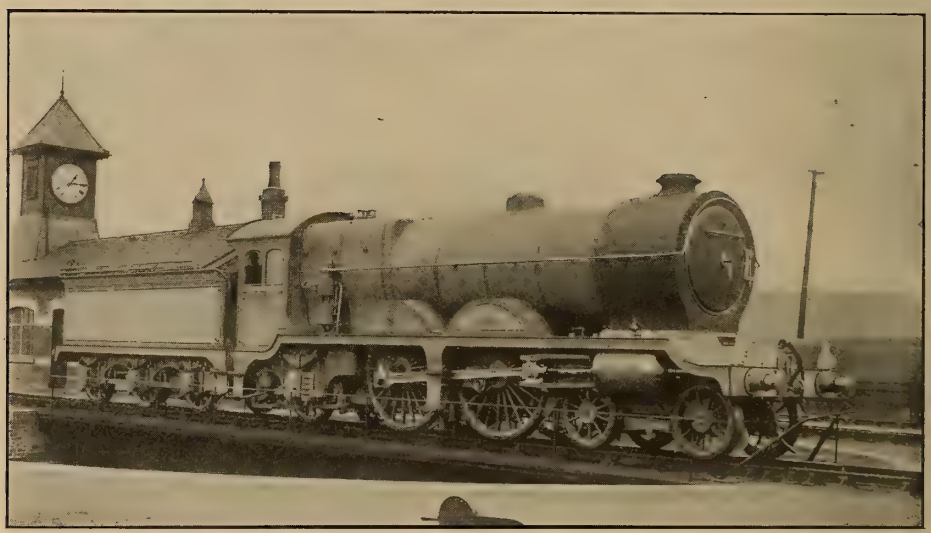
CALEDONIAN RAILWAY 4-4-0 CLASS EXPRESS ENGINE

GREAT NORTHERN RAILWAY 4-6-2 CLASS EXPRESS ENGINE. SWINDON WORKS

cost, mean endless nursing, with the liability to become troublesome at any moment. It is an admitted weakness of the inside cylinder engine that it is difficult to obtain ample bearings, though the advent of the built crank, with its absence of fillets at the ends, has improved matters. For the high, though now common, load of 18½ tons, a bearing 9 inches diameter by 12 inches long, or its equivalent, should be the standard aimed at.

the most useful express engine of the present day, and it is likely to be so for some time yet. With inside cylinders it is an ideal engine for steady running, the wheel base is flexible and comparatively short, it has a deep firebox without much slope in the grate, it is easy to make a pleasing design of it, and, altogether, it is still the typical British locomotive.

Its chief defect is that it is lacking in boiler power and adhesive weight to handle very heavy fast



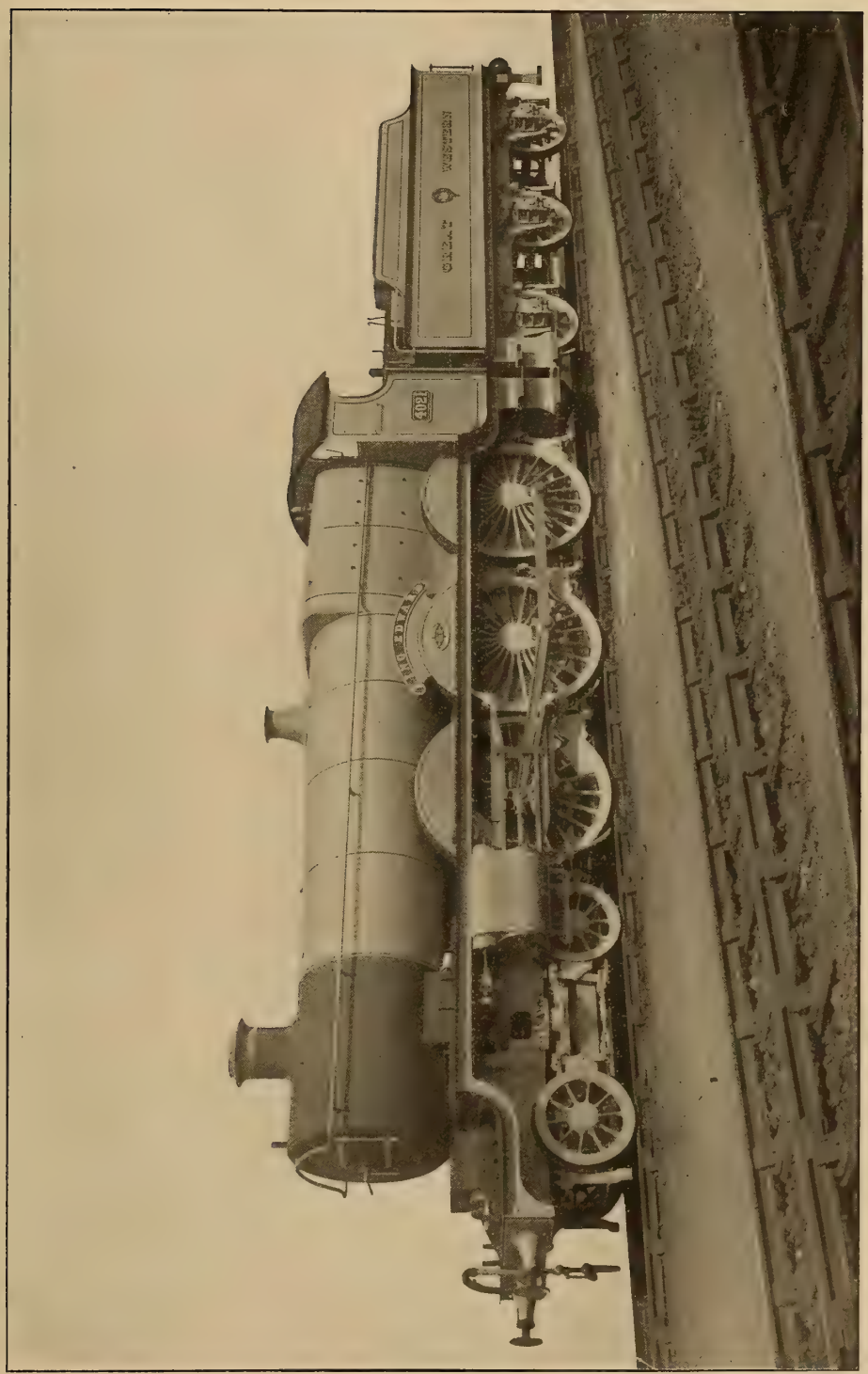
EXPRESS LOCOMOTIVE FOR NORTH BRITISH RAILWAY, 4-4-2 CLASS. CYLINDERS 20 BY 28 INCHES, WEIGHT 74½ TONS

Fifty miles per hour uphill on ordinary inclines and seventy down means a driving wheel neither very large nor very small, and 6 feet 6 inches seems to be a size that many have found suitable for express engines. A very level road might adopt 7 feet, with the advantage of a lower piston speed or a longer stroke than 26 inches, or a very hilly road might prefer 6 feet to obtain greater power, though in this case, at a high speed on the level, power is often lost by choking in the exhaust passages, owing to the high piston velocity.

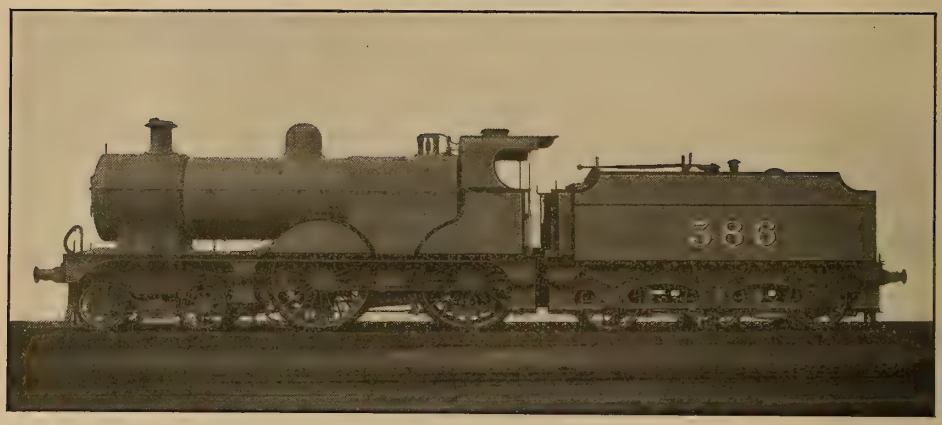
There is no doubt that the four-coupled engine with leading bogie is

trains. The reduction in weight obtained by the introduction of steel instead of copper tubes, and direct firebox stays instead of roof bars, has permitted an increase of size in the boiler; but 18½ tons on the driving axle and 18 on the trailing seems to be the limit, and for some trains this is not sufficient adhesive weight for all weathers.

In this difficulty we are not assisted by the introduction of the "Atlantic" type, which certainly may carry a larger boiler, but the adhesive weight remains the same, and this is its chief defect. The Atlantic engine has not been a conspicuous success anywhere, though it has been mod-



EXPRESS PASSENGER ENGINE, 4-6-0 CLASS, GREAT WESTERN RAILWAY. SWINDON WORKS

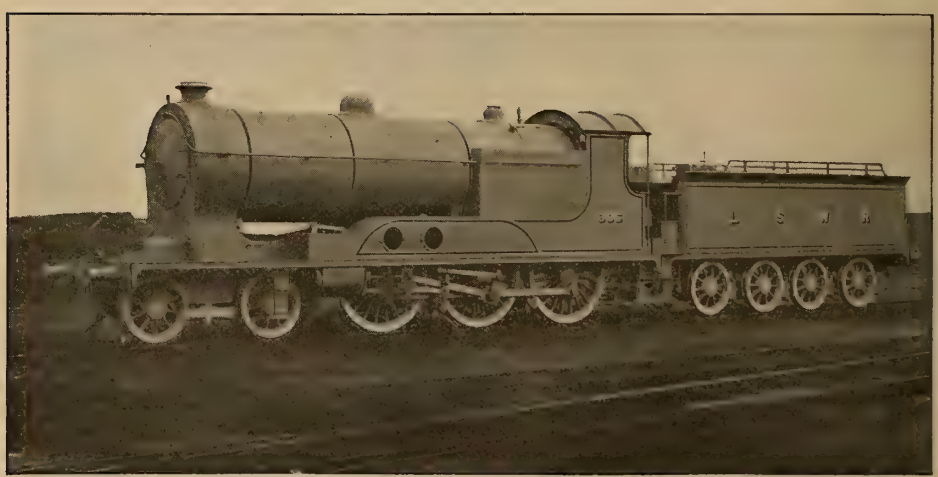


MIDLAND RAILWAY 4-4-0 EXPRESS PASSENGER ENGINE. TOTAL WEIGHT 89 TONS. DERBY WORKS

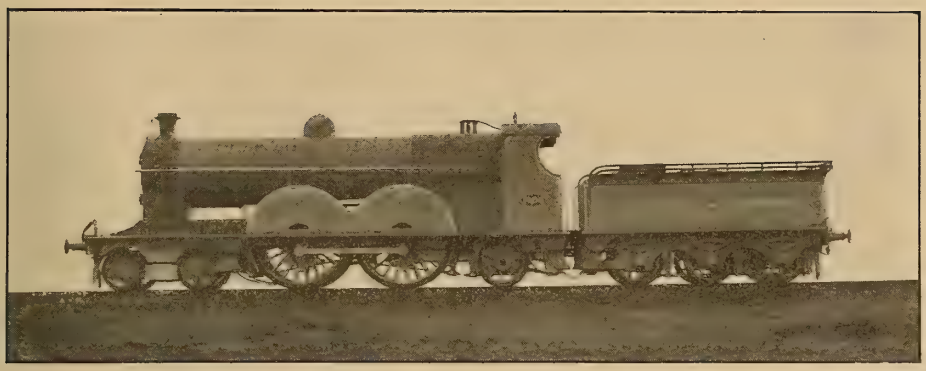
erately successful on fairly level and straight roads. Heating troubles have given it a bad name, though why they exist is not easy to see. The journals of the trailing axle being outside and all the others inside may have something to do with it, as the rolling of the engine would be likely to overload the trailing journals more than the others. If a trailing wheel of at least 4 feet 6 inches diameter were adopted, then inside bearings with under-hung springs could be arranged, thus getting all the engine journals in line. The deep firebox consequent on the low trailing axle is the main advantage of the Atlantic as compared with the six-coupled engine.

We have heard of comparative tests of the two types with a boiler that would fit either; but an engine with a shallow firebox is not really an Atlantic engine at all, even though it has a small trailing wheel.

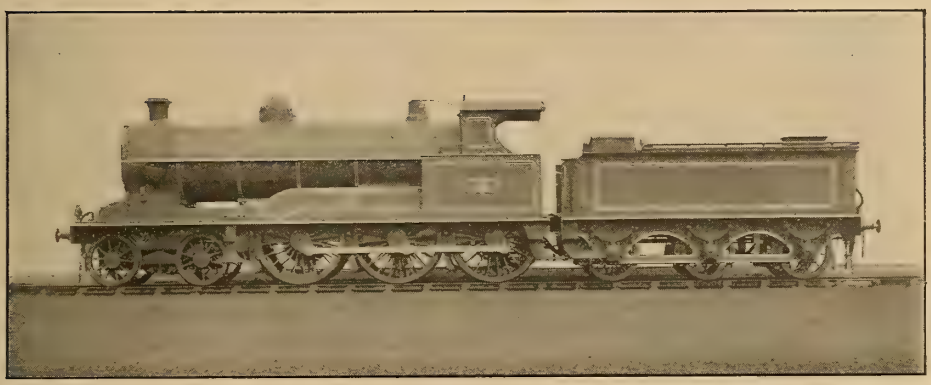
It is its freedom from slipping that puts the six-coupled engine far ahead of its competitors and makes it so very reliable for important trains. Its chief defect is the shallow fire at the back of the firebox and the sloping grate, owing to the posi-



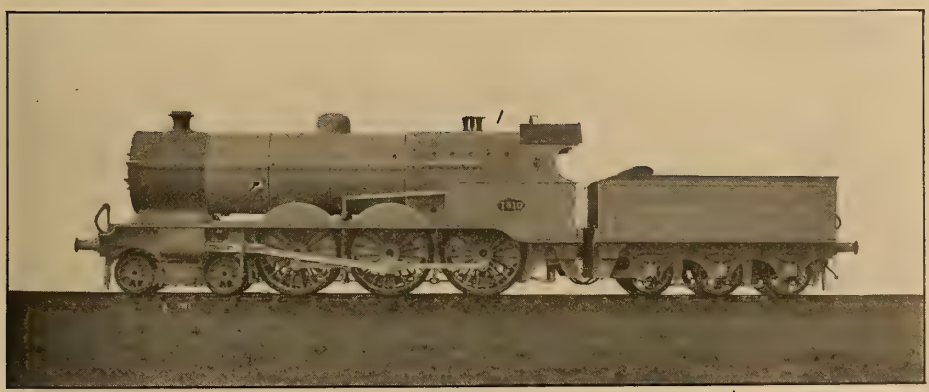
LONDON & SOUTHWESTERN 4-6-0 CLASS FOUR-CYLINDER EXPRESS ENGINE, WITH FEED-WATER HEATER IN TENDER



LANCASHIRE & YORKSHIRE RAILWAY 4-4-2 CLASS EXPRESS ENGINE. TOTAL WEIGHT 58½ TONS.
HORWICH WORKS



LONDON & NORTHWESTERN 4-6-0 CLASS EXPRESS PASSENGER ENGINE. CREWE WORKS



LANCASHIRE & YORKSHIRE 4-6-0 CLASS FOUR-CYLINDER EXPRESS PASSENGER ENGINE. HORWICH WORKS

CALEDONIAN RAILWAY, DUNALASTAIR CLASS 4-4-0 ENGINE. DESIGNED BY MR. MC INTOSH,

tion of the trailing axle. Holes in the sloping fire are easily made by a strong blast, with the consequent falling off in steam production.

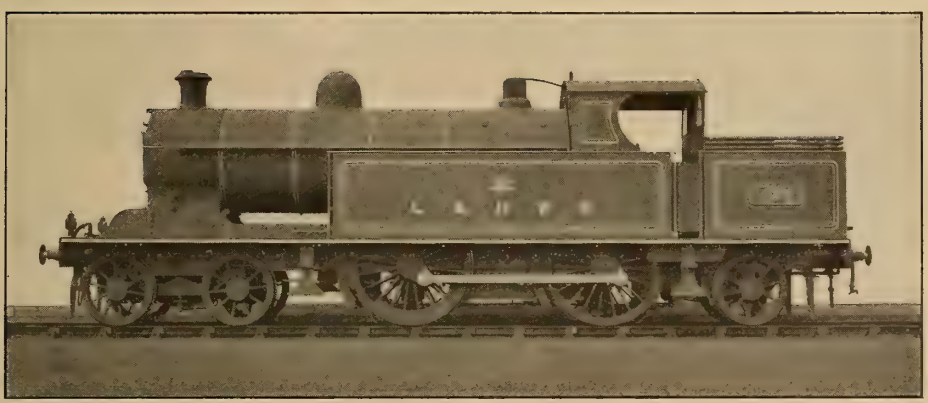
To come more closely to the consideration of the six-coupled type, it is obvious that the design that lends itself most to the minimizing of its inherent defects is most to be preferred. This at once points to a reduction to a minimum diameter of the coupled wheels to allow of the firebox being made as deep as possible, and also in the case of an inside cylinder engine driving on the front axle to allow of a connecting-rod as long as possible, by bringing the front and intermediate coupled wheel centres closer together. To carry the heavy weights and to take the high piston pressure large journals are absolutely necessary, or the plague of heating will destroy the efficiency of the finest engines. If we are not hampered by conservative ideas of what has been thought sufficient in the past, it will not be difficult to make this right with the straight axles, although the crank axle on an inside cylinder engine is more troublesome. The whole work of the engine is done through it, and the bearing should extend round 180 degrees. The ordinary distance of 2 feet 4½ inches between centres of cylinders with the valve chest between the cylinders will not permit of journals of greater length than 7½ inches, which is quite inadequate, and, consequently, the necessity arises of bringing the centres closer and of placing the valve chests above, in order to obtain a journal 9 inches long. If more than this is required, then dishing of the wheel must be resorted to and the guides put out of centre with the bearings.

The outside-cylinder, six-coupled engine, with its long connecting-rod and direct thrust on the coupling rods, its direct motion and large driving bearings, has apparently some decided advantages over the inside cylinder type, with its greater frictional resistance in the driving axle-box, its rocking shaft motion and comparatively short connecting-rod.

Each design has its supporters, but this much may be said for the inside-cylinder engine, that the greater steadiness of running, due to the closeness of the centres of cylinders, probably balances all its other defects.

The six-coupled engine with four cylinders seems to be coming into favour, but it is too soon to pronounce judgment on it. The turning effect of the four cylinders is no better than two, but the balancing of the moving parts is much better and the stresses are all reduced. It necessarily has some of the chief defects of both outside and inside-cylinder engines, but it must also have their advantages in some degree. The double sets of valves are usually driven by one set of valve gearing,

GREAT NORTHERN RAILWAY 4-4-2 CLASS FOUR-CYLINDER COMPOUND ENGINE, CAPABLE OF OPERATION EITHER AS SIMPLE OR COMPOUND. DONCASTER WORKS



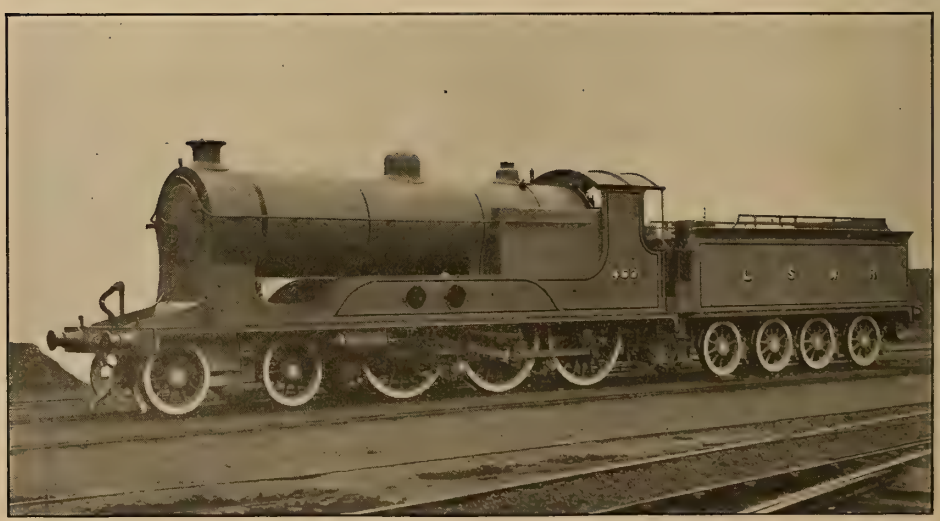
LONDON & NORTHWESTERN RAILWAY 4-4-2 CLASS TANK ENGINE. TOTAL WEIGHT 74½ TONS. CREWE WORKS

LONDON & NORTHWESTERN 4-4-0 EXPRESS ENGINE. TOTAL WEIGHT 59½ TONS. CREWE WORKS

LONDON & SOUTHWESTERN RAILWAY 4-4-0 ENGINE. DESIGNED BY MR. DRUMMOND AND BUILT BY DUBS & CO., GLASGOW

the use of piston valves making this quite an easy matter, and, altogether, the four cylinders do not add much complication to the engine. However, the British mind loves simplicity, and probably that feeling has something to do with British unwillingness to adopt the compound locomotive. Efficiency and reliability are more to a locomotive superintendent than economy in fuel, and those who provide public facilities are wise not to take risks for the sake of small gains. Compounding means very high boiler pressures with accompanying boiler troubles, and its keenest advocates do not suggest its application to all locomotives. The four-cylinder compound has worked well abroad, though it seems likely that some of its best work is done when running as a four-cylinder simple.

Compounding has now a strong competitor in superheating, a number of British railways being engaged at present in testing the claims made for it. Economy of fuel and water is certain in every case, but that does not sum up all the advantages of superheating. The increase in volume due to the superheat, as compared with the same weight of saturated steam, demands larger cylinders for its economical use, while giving the same power as the non-superheating



LONDON & SOUTHWESTERN EXPRESS LOCOMOTIVE, 4-6-0 CLASS, FOUR CYLINDERS

engine. This, again, permits of a lower boiler pressure being used, say a reduction from 180 to 165 pounds, assuming that 20-inch cylinders were substituted for 19-inch on an engine fitted with a superheater. This means a great saving in wear and tear of the boiler. Of course, piston valves are imperative, and forced lubrication of the cylinders and valves practically a necessity. If the valves are of the inside admission type worked by a rocking shaft, the eccentric rods will be open. Speaking generally, one would expect that the locomotive fitted with a superheater would require more skilled driving and attention as regards repairs. There is no doubt of the economic value of superheating, but confidence in its practical application has still to make some headway amongst locomotive engineers.

A most important adjunct of the modern express engine is its tender. The long non-stop run has kept down its size rather than increased it, for it has compelled the extensive use of the water pick-up apparatus. It is easy to carry sufficient fuel, but it is something of a handicap to an engine to begin its run with 22 tons of water behind it. Of course, if the pick-up apparatus is used, the underframes of the front carriages have to take the splashing. Pick-up tenders can be run on three axles with the advantage of fairly large wheels; larger tenders, which carry all their supply, are carried on two bogies, usually with 3-foot 6-inch wheels. As with the engine, so the tender axles should have large bearings to avoid heating. The horseshoe form of tank carrying its water at the back and sides, with its coal on the floor, may possibly be steadier, as it does not allow so much surging; but with the tank with the sloping top the fireman's work is much easier, not having to shovel from the floor level.

In conclusion, it may be said that, although broad general principles govern the successful designing of modern express engines, there are many apparently minor practical details which make or mar its success. No better instance of this can be found than in the details and arrangement of the blast pipe. Every 1-16-inch increase in the diameter of the orifice is a clear gain in reducing back pressure, while the form of the nozzle and its setting to the chimney may make all the difference between success and failure in automatically controlling steam production, according to the work to be done. In valve setting and in lubrication likewise important results often follow very small changes.

The modern express engine seems to have still a considerable lease of life, but signs are not wanting that sudden changes may take place in the near future. No other kind of engine has to do its work under such rough conditions, yet it has held its own by sheer efficiency and become the pride and interest of its designers and producers.

THE RIVER TUNNELS AT NEW YORK

By J. F. Springer

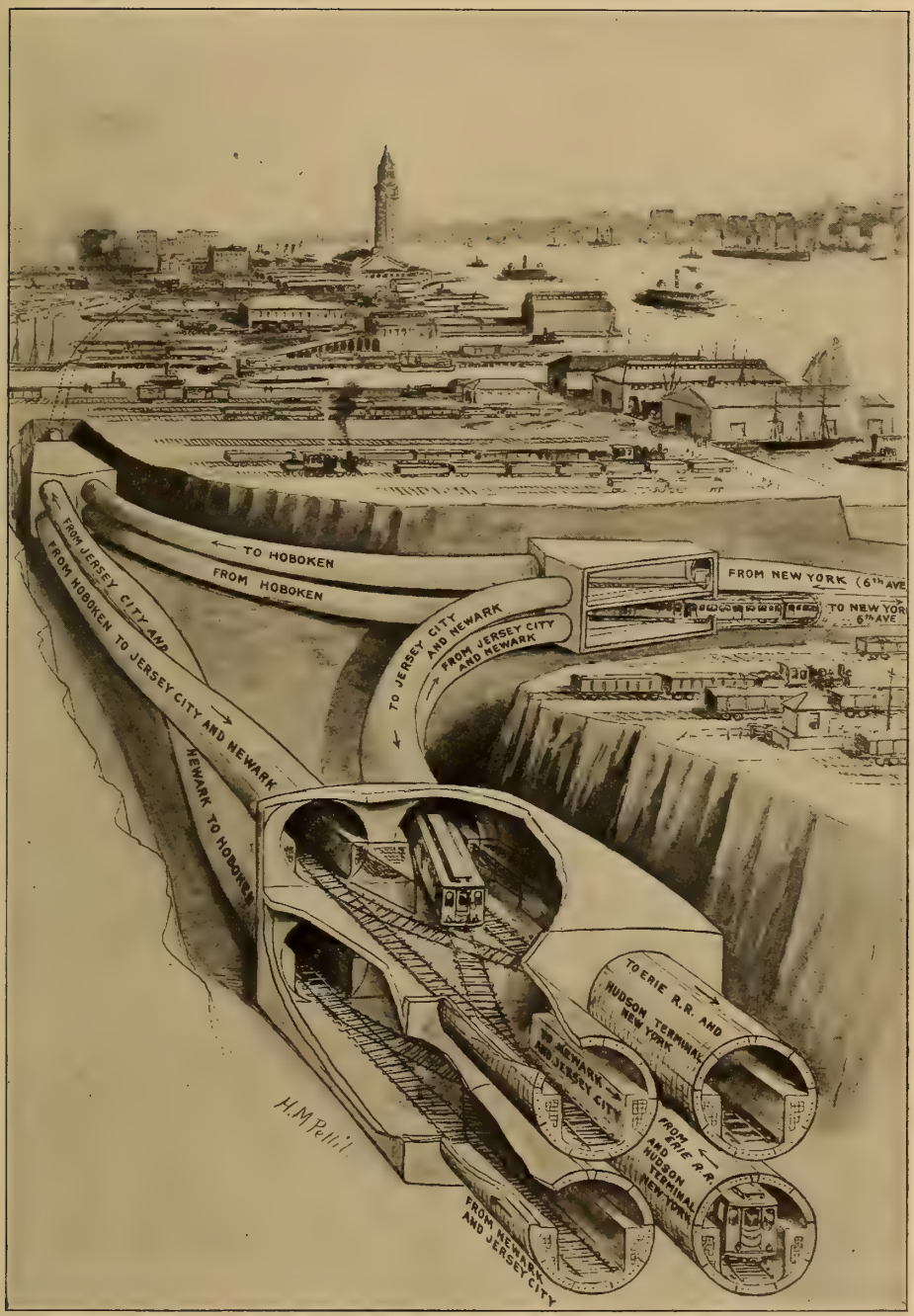
NEW YORK is the second largest city in the world. She has, probably, the very greatest water-front of any city of ancient or modern times, while her upper New York Bay is one of the most commodious harbors of the world. This city is thus magnificently situated with respect to international trade. This location has, no doubt, been a large factor in the interplay of cause and effect which has operated to bring her in a short century out from a position of comparative obscurity and unimportance and place her in 1910 in company with London. These two cities now dominate the commercial world. But we must not forget the great *hinterland* back of New York. It is the development—unparalleled in the history of the world—of these 4,000,000 square miles of territory that has made necessary a port and metropolis of the significance of this city.

But if we look at a railroad map of New York and its environs, we may at once see that her very situation in the midst of a wealth of navigable waters has well-nigh cut her off from all direct railway connection with the rest of the United States. In fact, Greater New York is situated almost exclusively upon islands. There are five boroughs. But only one of these three is on the mainland. Manhattan, the most important borough and itself the home of 2,000,000 people, faces the bay, has the East River upon one side, the Hudson River upon the other, and the Harlem River to its back. Across this last body of water—called a river—pass the tracks of the only direct railway connections possessed by New York with the continent. And one of these railway lines must pass about 150 miles to the north before it secures connection with the great bulk of the United States lying to the west. All other railways approaching from this immense section of country have their terminals separated from the city by the Hudson River. Final entrance of the passenger traffic has been, until recently, effected by ferry boats.

Further, the tremendous concentration of population in lower Manhattan during business hours is wonderfully reduced at their close. Only a portion of those who depart have their homes to the north on the island itself or the section of mainland across the Harlem River. Great numbers find their way eastward to the Borough of Brooklyn or other nearby parts of Long Island. Other multitudes flock westward to the New Jersey shore. A smaller number go south across upper New York Bay. Now until recently there was no interurban means of transport east, west and south except by the ferries and two bridges across the East River.

So, then, the navigable water, which is everywhere in New York and which has been the means of its exaltation to the position of much the greatest port of the New World, is likewise the cause of much hindrance to her own population and to that which flows in and out from the country at large. There is to be reckoned against these debits a credit—the distribution of incoming freight is greatly facilitated by the abundance of waterways. But, on the whole, the isolation has been well-nigh intolerable, because seriously inconveniencing the passenger traffic.

Indeed, the pressure has at last become so great that the elastic limit of the financial and physical resist-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H.M. Pelli

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FIG. 1.—VIEW OF THE ARRANGEMENT OF THE UNDERGROUND TUBES IN JERSEY CITY, N. J.

ance has been overcome. The construction which is already accomplished, or in an advanced stage of completion, will make Manhattan Island the centre of a wonderful system of passenger transportation. With the exception of three additional bridges—two of which are now open—this will all have been effected by sub-aqueous tunnel construction.

Manhattan Island is about 15 miles long. The New Jersey bank across the Hudson River is surmounted by the famous Palisades. These extend as far south as a point about opposite Twenty-third street. Through these hills the Pennsylvania Railroad is constructing its permanent way. This dips beneath the Hudson and enters New York below the surface at about Thirty-third street. Continuing eastward, it passes through the sub-structure of the great station in process of erection, and thence completes the underground transit of the island and finds its way, by four tubes beneath the East River, to the Long Island shore. This will enable the Pennsylvania Railroad not only to enter New York City, but to make its way out to north and east. At the lower end of Manhattan there is a sub-aqueous connection with Brooklyn now in operation as part of the New York Subway. To the north, at Forty-second street, there is a similar connection with Long Island, known as the Steinway Tunnel. This last is not yet in continuous operation. On the west, the Hudson Companies have constructed interurban connections with the New Jersey side of the Hudson River south of the Palisades. One of these connects the southern part of lower Manhattan with Jersey City, while the other joins the northern part of lower Man-

FIG. 2.—NEW TERMINAL OF THE PENNSYLVANIA RAILROAD IN NEW YORK DURING CONSTRUCTION

hattan with Hoboken, both passing the Hudson sub-aqueously. It will thus be seen that there is, altogether, a multiplicity of tubes running beneath comparatively deep water. Taken as a whole, it constitutes the greatest piece of sub-aqueous engineering ever undertaken.

The method universally employed at New York in penetrating through the strata underlying the rivers has been the pneumatic procedure. This process depends upon the fundamental principle of the impenetrability of matter. Two particles cannot both occupy the same space at the same time. We are all very familiar with this when the two portions of matter are solid or liquid. But when one is a gaseous substance the case is somewhat different. But the principle is just as true. Only we must remember that gaseous matter is easily compressible. This introduces another factor. In order that the space occupied by a quantity of air, say, shall not be encroached upon by ordinary liquids and solids of a highly incompressible character, such as water and sand, it is necessary that the tension of the air shall be equal to the pressure exerted by the liquid or solid. As we go beneath the surface in our efforts at excavation, we find that there is often a very serious difficulty encountered in connection with the ingress of water. Portions of the surrounding solid material may be kept in place by supports, but it is impracticable to restrain the water on the face of the excavation by this means. As we go deeper, the hydraulic pressure increases and the problem becomes more difficult. So that, if we would go on, this constantly increasing pressure must be equaled.

It is possible to do this with air. But whatever the pressure to be resisted, the air must be compressed to at least the same tension. If we have regard to what is ordinarily in engineering practice the largest factor to be considered—the pressure arising from water and other material under a hydraulic head—we are able to calculate the precise tension required for exclusion at any given depth below water level. For every vertical foot of penetration below the hydraulic level the tension required increases 62 1-3 pounds per square foot, or .433 pounds per square inch. At a depth of 50 feet this would amount to 21.65 pounds per square inch, or nearly one and one-half atmospheres. At 100 feet, it would, of course, be 43.30 pounds. It is customary, however, in practice to maintain a pressure somewhat in excess of that required by the hydraulic head alone.

Now we may divide sub-aqueous excavation into vertical and horizontal. In the former, the pressure required at a given moment is that indicated by the depth below the water level of the point of excavation at the time. This constantly increases as penetration goes on. In horizontal tunneling, however, there would be no change in the tension, on account of the constancy of level. If the tunnel dips or ascends, though, a variation will, of course, enter. But with tunneling there is a complication which proceeds from the fact that there is a variation in level between the points determined by the top and bottom. The air pressure suited for the top will be too weak to accomplish exclusion at the bottom. It might be thought, at first blush, that this could be easily dealt with by simply bringing the air pressure to the maximum required at the bottom. This, however, would have the effect of introducing a tension in excess of the hydraulic pressure at higher points, and thus would be produced a condition similar to that resulting from increasing the steam pressure above the strength of the boiler. When such an excess occurs in tunnel work, fears are to be entertained lest the compressed air may force its way out at weak or porous points. If this occurs to any considerable ex-

* The possibility of pumping away encroaching water or other matter is here disregarded.

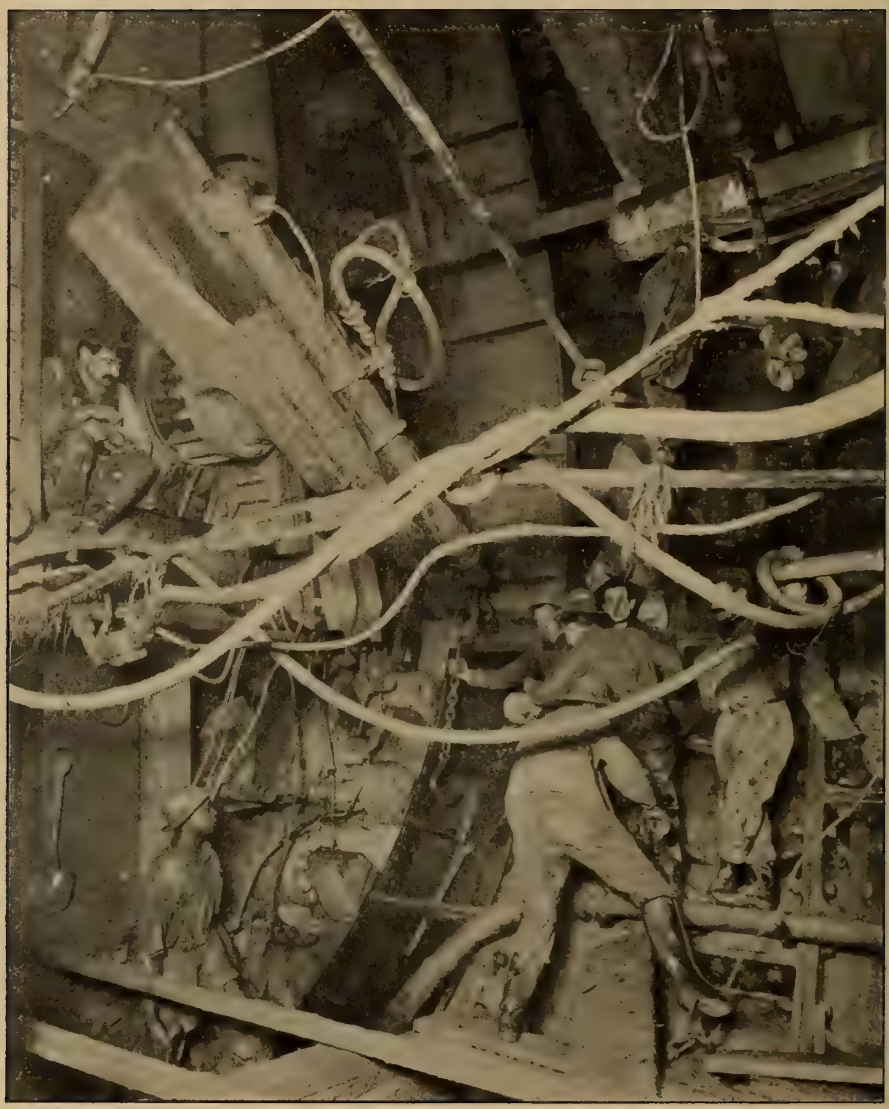


FIG. 3.—ERECTION OF STEEL WORK IMMEDIATELY BACK OF SHIELD IN EAST RIVER TUNNEL OF THE PENNSYLVANIA RAILROAD

tent, then the air pressure in the tunnel will fall. Upon the removal of this support a caving in of solid material and inrush of water are to be expected. If a tunnel has a height of 18 feet, the extreme difference in hydraulic pressure amounts to 7.79 pounds per square inch. But a "blow" may occur irrespective of any impossibility of adjusting the air pressure to all levels. All that is necessary is that a sufficiently porous point be reached. This may occur from the change in the character of the overlying strata or from a reduction of the thickness of the soil intervening between the top of the tunnel and the river bottom above. And "blows" may prove exceedingly disastrous. Twenty men were drowned thirty years ago in an occurrence of this kind during the

early efforts to construct a tunnel under the Hudson River.

There is another very considerable difference between horizontal and vertical excavation. In vertical work there are no overlying strata. In the case of the tunnel the weight of material overhead becomes a very serious factor indeed. An air tension equal to the hydraulic pressure will keep the water out—from every direction. But the solid material overhead may, under exceptional circumstances, be pressed down by a pressure comparable with its actual weight. This is about two and one-half times that of water. However, under ordinary conditions, the overlying strata soon become self-supporting as one ascends. Between the lowest point of self-support and the roof of the tunnel lies material whose fall is to be expected. The air pressure, whether great or small, cannot be relied on to support this. The reason for this circumstance is the porosity of the soil. If the compressed air could not penetrate the earth and get above it and the imbedded boulders, then the air pressure might be expected, ordinarily, to assist in keeping the roof intact. But with the air pressure above and below its particles the same, the material will fall under the influence of gravitation. It is necessary, then, to provide an air pressure to withstand hydraulic thrusts and a mechanical support to oppose the weight of overlying loose material.

To meet the conditions outlined, the usual modern practice in subaqueous tunneling is to operate a device known as a shield, to support the roof permanently to the rear of the shield and temporarily in advance of it, and to carry out the excavation and introduction of supports under pneumatic pressure. The shield, as ordinarily used at New York, is not an excavator. Its office is to provide a temporary mechanical support for the roof at the head of the tunnel and just back of the point of actual excavation, and at times to supply a bulkhead for the maintenance of the tunnel to its rear against any sudden outrush of compressed air or inrush of material and water.

The first shield was patented by Mr. M. I. Brunnel nearly a century ago (1818), and subsequently used by him in his first effort (1825-1828) to tunnel beneath the Thames. A second shield, similar in its main features, was employed in the final and successful effort (1835-43) to construct the Thames tunnel. These shields were used without the assistance of compressed air.

As an example of very modern practice, the type of shield used by the Hudson Companies in constructing the tunnels connecting Manhattan Island with the New Jersey shore may be cited. There was a cylindrical shell of steel of the diameter of the excavation to be made. This was provided with a cutting edge of cast steel, consisting of assembled segments. Within the shell was arranged a vertical bulkhead provided with a number of doors, which permitted the passage of workmen, tools and explosives. The shell extended to the rear of the bulkhead, forming what is called its "tail." The lining of the tunnel was erected within the tail. It will thus be seen that the tail of the shield continually enveloped the last constructed portion of the permanent lining. In advance of the cutting edge the actual excavation took place. The manner of accomplishing this would vary with conditions. Sometimes these were exceedingly difficult. At times the material would be rock for a few feet from the bottom up. This would be overlaid with soft material. The soil would first be excavated and the roof and other portions of the excavations supported by temporary timbering. The underlying rock would then be dealt with. To carry on blasting operations and maintain the integrity of the timbering was the problem to be solved. If the rock extended up-

FIG. 4.—DEPOSITING CLAY IN THE EAST RIVER AT POINT WHERE TUNNELS WERE CONSTRUCTED

wards to a point near the roof, the problem would be still further complicated by the restricted opportunity to take care of the overlying soft material. The excavation would be carried on until a complete cross-section had been cleared ahead to a point permitting the advance of the shield the width of a ring of the cast-iron lining. The shield could then be pushed ahead. This movement was effected by means of hydraulic jacks. Sixteen of these were disposed around the circumference of the shield between the bulkhead and the last erected ring of the lining. These jacks had a diameter of 8 inches and a possible extension of 30 inches. However, only 24 inches were required to accommodate a ring of castings, so there was sufficient margin to allow for clearance. The jacks could be worked separately or not, as desired.

Now, of course, the space ahead of the bulkhead of the shield is under air pressure, as well as the section of the tunnel to the rear. Indeed, this is the point where it is especially required. The soft material ahead is often very porous, and would, in consequence, permit the exit of large amounts of air. To meet this condition the timbering would be sealed with clay. Another method of dealing with the porosity of the strata encountered in the upper part of an excavation is to place a blanket of clay overhead on the bottom of the river above.

This method was employed in certain tube excavation work done by the Pennsylvania Railroad beneath the East River Considerable difficulty was experienced under certain conditions in adjusting the air tension to the extreme variations of the hydraulic pressures of a vertical diameter of a tunnel. The tubes were of large cross-section—23 feet; so that the difference between extremes would be considerable—about 10 pounds per square inch. It is said that when the air pressure was just equal to that of the water at the roof the bottom would be soft and the shield insufficiently supported. The roof was at times but a few feet thick, so that a tension competent to keep the bottom dry would be insufficiently resisted by the river and the intervening stratum. To meet these conditions a compromise was adopted. The pressure would be

kept at an intermediate point and the bottom of the river blanketed. A clay obtained from the bottom of the Hudson River at Haverstraw was used to the amount of, perhaps, a quarter million cubic yards. This deposit had to be removed subsequently to the performance of its service. The cost of the blanket, including its removal, was about $300,000. When the space ahead had been sufficiently excavated over the whole face and the shield had been advanced, another ring of cast-iron plates would be put into place. In the case of typical construction by the Hudson Companies these were ten in number—all duplicates, except the key plate used to effect closure. The ordinary casting weighed about 1,100 pounds, and had flanges on all sides to permit bolting up of longitudinal and transverse joints. The key would be varied in position generally, in order to break the longitudinal joints. In order to put these heavy castings in place, a mechanical erector was employed. It was found better to operate this device independently of the shield. A central lug was cast on each plate, and this enabled the erector to grasp and readily balance it. It will be understood that difficulty would arise in preserving the alignment. In order to correct deviations, special rings having their front and rear faces in non-parallel planes would be used. In fact, this expedient enabled curves to be constructed. Fifty-five bolts were used in securing a pair of rings together, and three bolts joined segment to segment to form the ring. There thus seems to have been used about eighty-five bolts per ring. These were 1¼ inches in diameter. It is to be especially noted that these had their threads formed by a cold

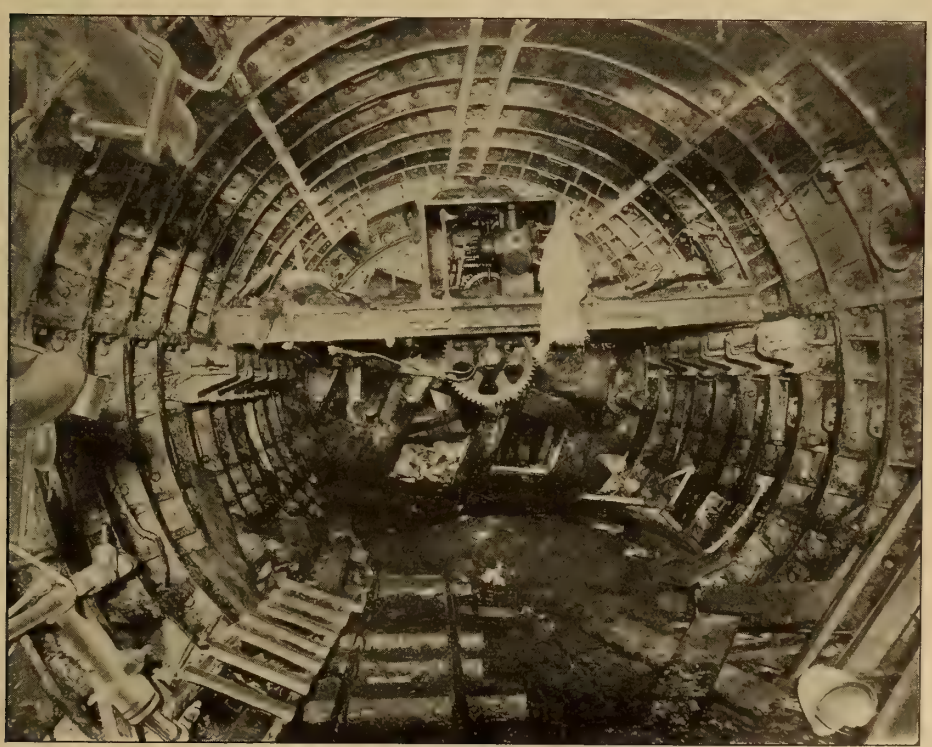


FIG. 5.—SHIELD USED IN THE CONSTRUCTION OF THE HUDSON TUNNEL. DESIGNED BY JACOBS & DAVIES; HYDRAULIC WORK BY THE WATSON-STILLMAN COMPANY; STRUCTURAL WORK BY THE LOGAN IRON WORKS

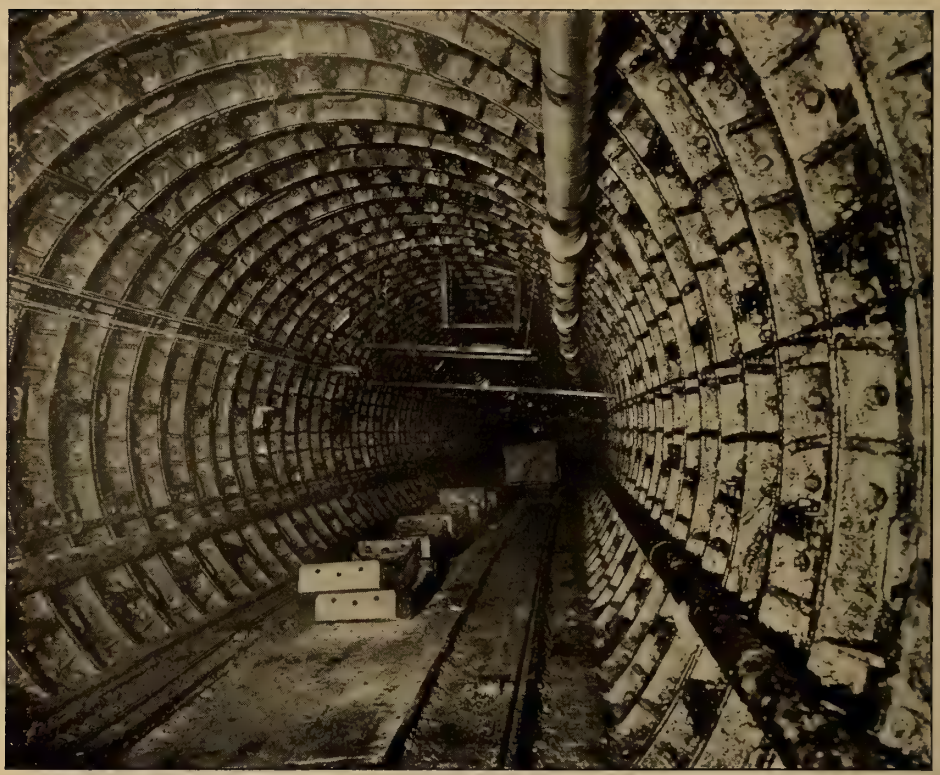


FIG. 6.—VIEW OF THE HUDSON AND MANHATTAN TUBE DURING CONSTRUCTION

rolling process. Such bolts were rolled by machines built by the Waterbury Farrel Foundry & Machine Company, of Waterbury, Conn. It was found difficult to prevent rotation of the shields. When this rotational deviation had accumulated to or near a troublesome point the shield would be brought back to a more correct position.

It will readily be understood that where we introduce compressed air into a tunnel for the purpose of preventing by pressure the ingress of water, etc., at the heading, we have at the same time brought to bear an equal pressure at the bulkhead which marks the rear of the tunnel section under pneumatic conditions. In the construction work carried out by the Hudson Companies under the direction of the engineering firm of Jacobs & Davies, the air tension is said to have attained, for a short time, the intensity of 48 pounds per square inch above normal. The bulkhead in a tube where such a tension exists will, of course, have to be strong enough to withstand it. This strength is not difficult to secure, especially as with a double bulkhead the pressure may be divided. But it must also be remembered that the air locks installed here must also be provided each with a resistance ring to receive the entire thrust against the cross-section of the lock. The usual battery of locks consisted of an emergency lock, two material locks and a pipe lock. The emergency lock was installed at as high an elevation as possible, and was capable of receiving fifteen men at a time. The two material locks were used for the passage not only of spoil, and the like, but also of the men under ordinary conditions. Three dump cars, each of one cubic yard capacity,

could be accommodated at one time in a lock. The tracks on which these were operated were continued through the locks. By providing suitable crossings at the ends, both locks could be used in either direction. The pipe locks had a diameter of 1½ feet and a length of about 35 feet. They were used for the purpose of passing long material, such as pipes and rails.

In Fig. 5 we have a view of one of the shields used by the Hudson Companies. The point of penetration here is Sixth avenue and Twelfth street. We are looking north and see the shield from the rear. The very considerable rotation is quite evident. The erecting mechanism intervenes between the upper part of the shield and the observer. By a close inspection of the view the rollers may be seen on which the erecting platform may be given a longitudinal movement. The cast-iron lining is everywhere in view. It will be noticed, however, that at this point the key plates were all given positions at the top of the tunnel. The central lugs are easily discernible. A number of the hydraulic jacks used to advance the shield are also in view, but may require close attention to make them out. However, one may be seen between shield and lining above and on the left at a point about 30 degrees below the top. Two others are fairly prominent on the right and below the erecting platform. In Fig. 6 we see a considerable portion of a tube at once. Some sections of rings are on the floor. In Fig. 7 we see a shield from the front. That it has experienced some rotation is plain. The more or less completed tube may be seen through some of the openings. That its service has not been without some effect upon itself may be seen by a close inspection of its condition. It may be interesting to know that in sub-aqueous work under the Hudson River a shield has been advanced at the rate of a foot every twenty minutes for a period of twenty-four-hours. This was through

FIG. 7.—FRONT VIEW OF A SHIELD. THE TUBE IS SEEN THROUGH THE OPENINGS

silt. The possibility of this speed is attributed by Mr. Davies, one of the consulting engineers, to the great strength of the shields. In Fig. 8 are seen four of the shields partially erected. The hydraulic jacks for these were built by the Watson-Stillman Company of New York.

The tubes constructed by the Pennsylvania Railroad Company constitute, perhaps, the largest single subaqueous undertaking ever attempted. These tubes underlie both the Hudson and the East Rivers. Confining ourselves to those under the East River, we learn at once that there are in all four tubes, each of about 23 feet diameter. Excavation was carried out to a maximum depth of about 90 feet below high water. Consequently, the hydraulic pressure would be 39 pounds per square inch. In actual practice, however, the extreme pressure, found at the bottom of the tunnel, was not fully opposed. The air tension employed corresponded to the hydrostatic pressure at the tunnel axis and varied from 30 to 34 pounds per square inch. The four tubes were all driven concurrently from both sides of the river. Air pressure was put on in the autumn of 1905, and each of the eight shields met its companion less than two and one-half years later, in March, 1908. The driving of the tunnels was carried out here, as under the Hudson River, by dipping down from both sides of the river. The material penetrated beneath the East River was quicksand, sand, boulders, gravel, clay and bed rock. The successful completion of four tubes totaling nearly three miles of length through such materials is really a great feat in subaqueous engineering.

The tubes, as they leave Manhattan Island and pass under the river to the Long Island side, are arranged in two pairs. There is a distance of about a block between the pairs on the western side. As they approach the eastern side they steadily draw nearer to each other. There are on both sides of the river two permanent vertical shafts, each corresponding to a pair of tubes. These were excavated for constructional and other purposes. To accomplish this excavation four great caissons were constructed. One of these was sunk through 16 feet of water, and all but one were so built as to be usable as pneumatic caissons.

The advisability of constructing the shafts will be understood by a consideration of the general conditions. The permanent way sinks beneath the surface at a considerable distance back from the Hudson River bank on the New Jersey side. In fact, the tunnel under Bergen Hill—part of the Palisades—is the first mile. Nowhere thence to a point a third of a mile eastward from the Long Island bank of the East River does the railroad rise to the surface. The distance from the great station to the eastern portal is more than two miles. It will thus be seen that the problem of ventilation between these points was a considerable one. The use of shafts on the opposite sides of the river in large part solved it. Further, from these shafts the shields could be pushed simultaneously beneath the river and towards each other, and would be convenient points for the passage of workmen in and out.

In selecting sites for the shafts the desirability of having locations where the tunnels would have a substantial mass of overlying rock was kept in mind. On the Manhattan side no difficulty was experienced. Quite close to the water's edge the underlying rock is found at a moderate depth. It extends out in an easterly direction, so that it was found possible to sink the shafts and have a very considerable horizontal thickness of rock in which to construct the initial portions of the tubes. On the Long Island side conditions were somewhat different. A profile of the tunnels at this point discloses deep pockets of soft material with two ridges of rock between.

One of these ridges was cut from the bank in the vicinity of the line of pier heads. The other was near the bulkhead line. The latter site was the one selected.

The two caissons on the Manhattan side were sunk to points within the rock and the shafts continued to the required level without the use of compressed air. The southern shaft, just south of Thirty-third street and east of First avenue, was excavated for its full section of 40 by 74 feet to a depth of 15 feet and for a reduced section of 20 by 25 feet to the level of the tunnels without the assistance of the caisson. It was found that but little water would be met with, although the bottom of the shaft would be about 80 feet below mean high water. It was also found that hard rock only would be penetrated. Consequently, the caisson would not be sunk to anything but an inconsiderable depth. The steel work was assembled and the caisson erected to a height of 40 feet. This construction was accomplished by building up from the bottom of the full-sized excavation, 15 feet below the surface. This caisson was built with inner and outer casings of steel, 5 feet apart. The structure was sunk to a depth of 31 feet below mean high water at the rate of 6 inches per day. The caisson of the northern shaft was built to a height of 50 feet. When at its final position, its top was about 12 feet above mean high water. The rate of sinking was about the same as with its companion. On the Long Island side the caissons were sunk to the full depth of the tunnel level, and they were likewise of steel. Each was 74 feet long and 40 feet wide on the exterior, and had dimensions 10 feet less upon the interior. The intervening space was filled with concrete. Four large circular openings were left, two on each side, to receive the tunnels. As these caissons

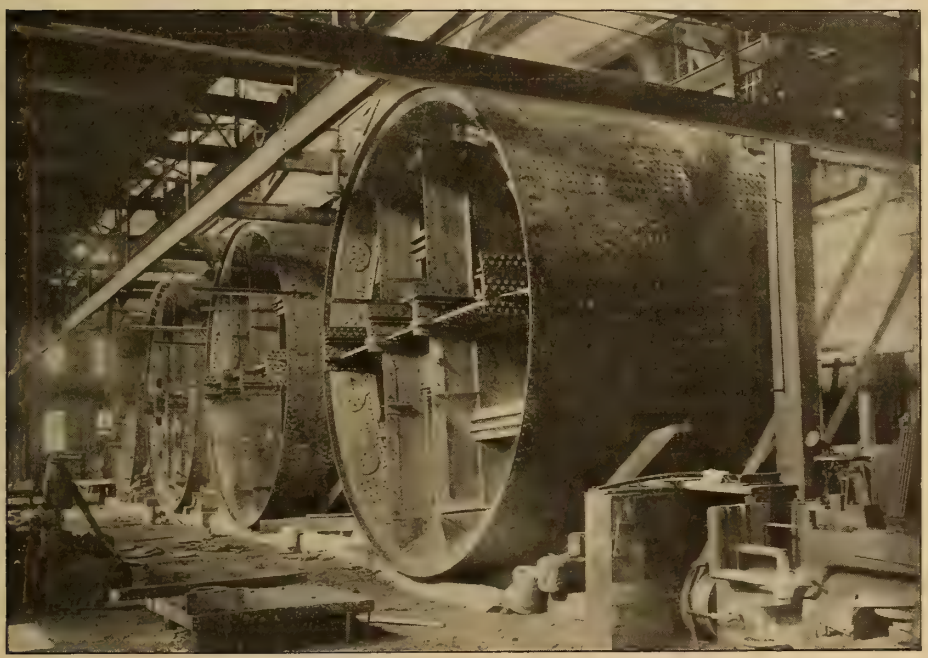


FIG. 8.—FOUR OF THE SHIELDS PARTIALLY ERECTED

were sunk by the pneumatic method, it was necessary to close the openings effectively until the final footings were reached. The steel bulkheads employed for this purpose were supported by steel girders on the inside. A substantial deck was constructed above the working chamber. The total penetration below mean high water was 78 feet. There was a vertical partition constructed in line with the tunnels and dividing each caisson into two chambers about 30 feet square. After the first 24 feet the penetration was accomplished through rock. This is, perhaps, a matter worthy of comment, inasmuch as caissons are not usually sunk for the purpose of penetrating rock, but of reaching it. However, as Messrs. Brace, Mason and Woodard observe in their paper on East River tunnels, there have been other and larger caissons sunk to a greater depth. The metal caissons used for constructing the six piers of the Hawkesbury Bridge, in New South Wales, Australia, were somewhat smaller in cross-section, but their average penetration below high water (H. W. S. T.) was 142½ feet. These were sunk by open methods, however.

Within the four shafts work was commenced on the construction of the eight shields for the penetration of the river bed. The profile along the line of the tunnels shows an inconsiderable amount of rock actually overlying the top. From shore to shore the material above the roof is almost exclusively of a soft and permeable character. It is, moreover, of a very uneven thickness, and at only a couple of points is this thickness considerable. We have here the conditions of difficult tunneling by the pneumatic method. It was found necessary to adopt the procedure, before referred to, of depositing a blanket of clay to assist in the retention of the compressed air. In fact, on the Manhattan side, where the natural stratum overlying the tunnels was thinnest, clay to the depth of 10 and 12 feet was put in place. How rapidly air may escape may be understood when it is stated that a record of air consumption was made by the northernmost tunnel heading proceeding from the Manhattan side, which reached the figure of 19,000 cubic feet of air per minute for a period of twenty-four hours. This consumption maintained for such a period seems to be equal to that observed upon the occurrence of a sudden blow-out.

In connection with the troubles originating from the inequality of the hydrostatic pressure to be overcome at the various levels between the top and bottom of a tunnel may be mentioned the experience had at the very beginning. Not long subsequent to the commencement of operations with the most southerly heading from the Long Island side it was found, as penetration into an enveloping stratum of sand was carried on, that it was almost impossible to maintain the shield at its proper level. This tendency to sink was due, no doubt, to an insufficient drying of the underlying sand. The air pressure was increased to a tension capable of driving the water from the bottom, the shield was on the rise, and had, in fact, about recovered the proper level, when the pressure of 9 pounds in excess of that required for the top of the tunnel resulted in blow-outs. In fact, rip-rap, sand and water now entered the tunnel, the latter two in considerable quantity. The necessary air pressure could not be kept up on account of the great wastage, and it was necessary to construct a temporary bulkhead and stop work until natural settlement of the overlying soil should effect a better sealing. It will be seen from this incident that, while sand may be a very easy material through which to effect penetration, it threatens success, because of its permeability to compressed air. When the shield was settling into the sand, as just described, it occasioned the breakage of

FIG. 9.—LOOKING WESTWARD IN THE PENNSYLVANIA TUNNEL, VIEW SHOWING IRON LINING AND CONCRETE ARCH BEFORE BUILDING CLOSING LENGTH FROM STATION

a number of the cast-iron segments used for the permanent lining.

Now blow-outs were by no means exceptional occurrences. When one took place, there was the possibility of an increased damage to the cover over the tunnel through erosion. In illustration of this, attention may be directed to an increase in the depth of water of 18 feet in about two days, which occurred over the southern one of the northern pair of tunnels close in to the Manhattan shore. It is said that the water at the point in question was normally 36 feet deep, and that beneath this were ordinarily 7 feet of blanket and 20 feet of river bed. There was an air loss of 10,000 cubic feet per minute and several small blows during the two days. Upon sounding for the depth of water, it was found to have increased to 54 feet.

The general method of driving the Pennsylvania Tunnels was the same as that employed by the Hudson Companies. However, there were variations in detail. The cast-iron lining was formed in segments, which, when assembled, gave a cyl-

inder 23 feet in external diameter. A single ring was 2½ feet long, and was composed of twelve segments, one of which was a key piece. The web varied from a thickness of 1½ inches at the centre to 2⅜ inches near the edges. Around the edges flanges were arranged, 11 inches deep. These varied in thickness from 2¼ inches at the root to 1½ inches at the tip. In order to unite these plates by close-fitting joints, the contact surfaces were machined. At the centre of an ordinary segment a hole was tapped to receive a 1¼-inch pipe. This was the grout hole. As each of the ordinary segments weighed about 2,020 pounds and the key 520 pounds, a single ring weighed 22,740 pounds. This would be about 9,096 pounds per lineal foot of tunnel. As there are about 15,600 feet of sub-aqueous tube between the shafts, we have for the total weight of permanent lining used under the East River over 70,000 tons. The lug which, with the Hudson Companies, formed an integral part of the ordinary segment, was here omitted. A gadget was employed instead, in connection with a corresponding pair of bolt holes near the centre. The device furnished a means by which the mechanical erector controlled the plate. However, a great deal of placing was done by hand, in spite of the fact that all pieces except the key weighed a ton each. At certain critical points in the tunnels where there was a change from rock to soft ground, steel rings were substituted for those of cast iron. It was expected that at such locations the lining might be subject to increased stress from unequal settlement. But no inequality of settlement appears to have been observed.

The metal lining was faced with a heavy layer of concrete—about 2 feet thick. On the outside the space between lining and the soil and rock was filled in with grout. The holes before referred to were employed for this purpose. It should be added that suitable recesses were left between flanges for the purpose of caulking the joints. As the shield would be advanced, there would be a slight settlement of the lining as the support of the tail was removed.

It was found that occasionally a segment would be broken in consequence of the advance of the shield. It will be remembered that, in shield work, the tail envelops the newest part of the lining and that the advance is secured by using jacks between the face of the lining and a bearing surface within the shield. It will readily be seen that a small tool or other piece of solid material might get caught between the under surface of the last ring and the tail shell and result in fracture of the cast iron when the shove is made. Further, the interposition of some foreign substance may displace the bearing of a jack against the ring face and cause failure of the flange. Finally, a difference of alignment between shield and final rings may occur through sinking of the shield or in the effort to secure penetration. An illustration of the former source of breakage has already been given. In penetrating soft material, it was sometimes found difficult, if not impossible, to advance the shield evenly all around the cutting edge. Thus it would sometimes be directed upwards at first and then by bringing the upper jacks into play it would be righted and the advance made. In such rocking movements fractures of plates would sometimes occur. It is recommended to employ taper rings, at suitable junctures, to relieve the stress between shield and lining. Such variation from the alignment would, of course, be small in any single instance and ordinarily capable of correction before it could accumulate to a considerable amount in one direction.

On the Manhattan side the surface of the rock slopes downwards and eastwards. But the dip of stratification is westward. This dip is considerable, being in the neighborhood of 60 degrees. In consequence, pieces

of rock, when broken loose, would often slide down and into the shield. Sometimes the overlying sand would come into view.

The shields used from the Manhattan side were erected in the shafts and shoved towards Long Island for a distance of, perhaps, 60 feet without the use of other than normal air. Likewise, short sections of the tunnels westward had previously been made in the solid rock by non-pneumatic methods. Bulkheads of concrete, including the air locks, were then put back of the shields. In order to secure a bearing to begin the eastward movement from the site of

FIG. 10.—ELECTRIC TRAIN FOR SERVICE IN THE PENNSYLVANIA TUNNELS

erection, rings of lining were set up and supported on the west by timbers placed across the tunnel openings on that side of the shafts. When the advance of 60 feet had been made to the east, it became advisable to employ pneumatic methods, as rock to a sufficient height extended but a short distance ahead. The cast-iron lining had been continued as the shields advanced. Within a section of this, perhaps 50 feet long, the air locks and bulkheads were placed. If one considers that the air lock is subjected to the same pressure per square inch as the face of the heading, one will understand that no uncertainty must exist as to the security of the anchorage. Ultimately this would mean, in the present case, that the 50-foot sections of lining must be held securely in position. It was deemed advisable to interlock the exterior of this lining with the irregular rock surface. This was done in the following manner: As the rings of lining were being put in place, plates $\frac{5}{8}$ inch thick and $13\frac{7}{8}$ inches wide were placed around in the circumferential joints. These were provided with radial slots matching the positions of the bolts which secured ring to ring. These plates would be put in place during erection of the lining in the shield. When the shield had advanced sufficiently, they would be driven outwards—a movement permitted by the radial slots—and form projecting planes, extending outward a matter of, say, 5 inches from the exterior surface of the lining. Eighteen such projecting surfaces were employed. When the space between lining and rock was grouted up, these planes formed a kind of reinforcement, tending to maintain the hardened grout in exact conformity to the surface of the excavation.

The shield work performed under the East River was, of course, not the first. At the same time, there was little or no precedent to guide where the material to be penetrated was rock or part rock. A considerable mass of experience has now been

accumulated, not only from the work, but also from that obtained in the construction of tunnels under the Hudson River. Beneath the East River three methods of dealing with an all-rock heading offered themselves. Either a pilot heading at the bottom level would be excavated for 10 to 30 feet ahead of the shield by ordinary methods, or the full face would be dealt with, or the centre heading procedure would be employed. There was considerable disadvantage experienced in using the bottom pilot heading. This arose from the blocking of the bottom when the rock above would be blasted out. In using the full-face method, the bottom would first be dealt with, then the upper part of the face.

Before a great deal of experience had been accumulated it was hoped that it might be possible to employ the full air pressure only in the excavation ahead of the shield. In fact, one or more shields were erected in contemplation of this. The bulkhead was closed across the bottom and fitted with air locks. However, no attempt was made to put this idea into actual practice. In fact, Messrs. Brace, Mason and Woodard state that experience gained while penetrating sand makes it clear that this is an impracticable thing.

Moreover, it soon became plain that it would be advisable to have an opening at the bottom of the bulkhead permitting the passage of muck cars. Certain shields on the Manhattan side were altered in accordance with this experience, and others on the Long Island side built in conformity therewith. It was found that a bottom heading was objectionable on account of delays from blocking. In time it was seen that by making a pilot heading, whose floor was at a considerable level and left some rock above but none on the sides, could be employed to advantage. A timber platform was constructed just in advance of the shield subsequently to taking out a portion of the bottom rock. The muck cars could be operated under this without serious interference from the blasting of the top section. But it was found better to leave but little rock overhead and to blast this down upon the track below. This system of centre-heading was found to be the most satisfactory where all-rock penetration was to be made. It is said, however, that the excavation where the rock occupied only a part of the cross-section was probably the most difficult of all. This required, at times, that blasting operations be conducted in connection with the maintenance of air pressure under severe conditions. Thus, when the material overlying the rock was not only thin but readily permeable, the escape of air would be great.

Before leaving the subject of subaqueous permanent way of the Pennsylvania Railroad in the vicinity of New York it may be well to call attention to the question of stability. It was thought that the underlying material in the East River would afford a substantial support without assistance. But with respect to the two tunnels under the Hudson River the case seemed different. There the tubes are, for a large portion of the distance, surrounded by a mud. It was feared that the action of the heavy live load might result in displacement of the structure. This contingency was rendered the more probable because of the fact that tunnel plus live load is of slightly less specific gravity than the enveloping material, and is thus, in a way, resting in the mud or water-bearing clay. It was proposed, therefore, to carry the vibrating load on a system of cast-iron screw piles. The heads of these were, by one plan, to pass through the floor of the tunnels by a sliding joint, and thus receive the live load directly. By another plan, the tunnel and piles were to be secured together. But, as the result of careful study and experiments, it was not deemed necessary or desirable to carry out either proposal, and the live loads that have since passed through the tunnel justify the wisdom of that decision.

SOME RECENT DESIGNS OF LOCOMOTIVES FOR SERVICE ON CONTINENTAL RAILWAYS

By Albert H. Bone

THE writer wishes, at the outset, to draw attention to the fact, indicated in the title, that this article makes no pretense to be inclusive, "some recent designs" only being described. The field is a large one, and many interesting designs have not been mentioned for want of sufficient room, while doubtless others have been overlooked.

Sufficient has been included, it is hoped, to give a fair idea of the general trend of locomotive design on the continent of Europe, as exemplified by the engines recently turned out by some of the principal locomotive works.

Whilst, in the case of some of the engines described, the experience of the writer is confined to seeing them at work on the road, a large number of them have come under his observation at the works of the builders, and for these latter, and also for some others, he is indebted to the makers for detailed information supplied. To all of these, and also to various locomotive superintendents, inspectors and other officials of the various railways, the writer wishes to make cordial acknowledgment of their kindness.

In calculating the maximum tractive force, the following formulas have been used, viz:

D_h = diameter of high-pressure cylinder.
D_l = diameter of low-pressure cylinder.
S = stroke of piston.
D_w = diameter of driving wheels.
P = pressure of steam in boiler.

Then for two-cylinder, simple-expansion engine

$$M.\ T.\ F. = \frac{0.75\,P \times D_h^2 \times S}{D_w},$$

and for four-cylinder, simple-expansion engines, the same formula multiplied by 2.

For compound engines having one high-pressure and one low-pressure cylinder:

$$M.\ T.\ F. = \frac{0.5\,P \times D_l^2 \times S}{2\,D_w},$$

or for compound engines having two high-pressure and two low-pressure cylinders, the same formula multiplied by 2.

All computations have been made according to the metric system and then reduced to British units, as have all measurements. The writer has done his best to check all calculations; but as they have involved many thousands of conversions, doubtless some errors will be discovered.

In the case of tank engines, the ratio weight on coupled wheels, divided by the maximum tractive force, has, wherever the figures were available, been calculated twice; once on the supposition that the engine was in full running order, with tanks and bunkers full, and again on the supposition that the tanks and bunkers were empty, but with full allowance of water in the boiler and coal on the grate. These two values of the ratio represent the actual maximum and minimum, respectively. The same has been done in the case of tender engines having a "traction

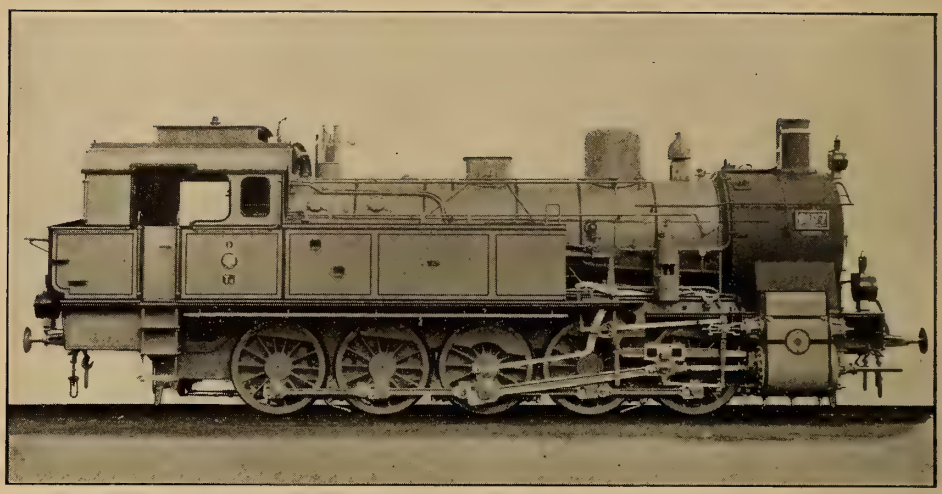


FIG. 1.—TWO-CYLINDER 0-10-0 TANK ENGINE WITH SCHMIDT SUPERHEATER, BUILT FOR THE PRUSSIAN STATE RAILWAYS BY THE BERLIN ENGINE-BUILDING COMPANY

increaser" or water tank between the engine frames.

In describing four-cylinder engines, the terms "balanced" and "divided and balanced" have been used in their ordinary sense, as usually understood—i. e., "balanced" indicating a cylinder arrangement in which all four of them drive to one axle, one pair on the right side and the other pair on the left side of the longitudinal centre line of the engine, being placed 180 degrees apart, so that, neglecting "couples," the reciprocating parts of each pair balance each other. By "divided and balanced" is meant a similar crank spacing, but with the inside cylinders driving to one axle and the outside cylinders driving to another.

In general, it may be said that the system of compounding adopted in the case of most of the French engines described is the De Glehn, or some modification of it. On the Prussian State Railways for fast passenger work the four-cylinder compound engines recently built have no intercepting valve, but are fitted with the later form of Von Borries starting arrangement. For other service, however, the two-cylinder Von Borries compound is still extensively built. In other countries a large variety of compounding systems are used, such as the arrangements of the firm of Maffei, also the Gölsdorf, Lindner, Von Borries, Ranafier, and several others.

In the case of engines using superheated steam for simple working, the only form of side valve used, so far as the writer knows, is the piston valve with inside admission; but for compound engines working with superheated steam flat slide valves are sometimes used for the low-pressure cylinder. When the drop-valve of the Lentz type has been used, it has been fitted in some cases to the high-pressure cylinder only; but in others it has also been used with the low-pressure cylinder.

Reference has not been made in detail to the fittings of various sorts to be found on the engines unless there is something unusual concerning them. In the case of engines using superheated steam on the Schmidt system the following arrangements are almost universal:

The superheater dampers are worked by an auxiliary cylinder fixed on the smokebox side, the steam supply being taken from the main steam pipe, so that the dampers remain shut when

the regulator is closed and are opened when steam is given to the engine cylinders. Hand regulation is also fitted in the cab for use when running. For use when "coasting," or running without steam, a by-pass cock is fitted in a passage which connects with both ends of the cylinder. This is generally worked by hand, but in some cases is kept shut only when the regulator is open, being pulled into the "open" position by a counterweight when the regulator is shut. With the exception of the Prussian State Railways, so far as the writer is aware, the piston valves are in all cases provided with spring packing-rings of one form or another.

On the Prussian State Railways a special form of axle box is very extensively used, having large bearing surfaces divided into three parts, an upper and two side bearings, the latter coming some distance below the centre line, and being capable of adjustment. All are lined with white metal. This box is somewhat expensive to make, but is undoubtedly a good form for use with engines having large cylinders and unbalanced reciprocating weights. The form of piston valve almost universally employed is a double-admission valve, having solid rings, working in bushings themselves provided with steam jackets, so that all parts of the valve and bushings are uniformly heated. Both valves and bushings are ground true to standard gauges, allowing about 0.002 inch clearance, the object in view being a practically steam-tight valve, working with a minimum of friction. The writer has been shipmate with this type of valve fitted to marine engines, though not with anything approaching to the accuracy of those in question. But with the triple-expansion engine one always has the comforting assurance that any leakage past the high-pressure plug valves is intercepted by the intermediate flat slide valve ordinarily fitted. In the case of single-expansion locomotives this is not so. On the whole, it is said that the solid-ring valves have given satisfaction on the Prussian State Railways; but it is interesting to note that experiments are being tried with spring-packed valves. It will be a cause for regret if the plain valve is ultimately found unsuitable, as it is undoubtedly a cheap form to manufacture, is not liable to breakage in service, and is very "easy" on the motion work if properly lubricated.

In general, drop grates are very numerous in all countries, as are variable blast orifices of one form or another.

Throughout the descriptions the name Walschaert is given to the form of valve gear sometimes known as Heusinger, the former name being more familiar to English readers.

TEN-WHEEL-COUPLED GOODS ENGINES

The ten-coupled or "Decapod" wheel arrangement was first used in America, where the 2-10-0 type was adopted. The "Reid" engines, built by Messrs Dübs & Co., of Glasgow, early in the nineties, were ten-coupled engines, and in 1904 Messrs. C. Stephenson & Co., Limited, of Darlington, designed and built for the Argentine Great Western Railway an experimental engine of the 2-10-0 type, which proved very successful in service and led to a further order for exactly similar engines. Since that time large numbers of ten-coupled engines, both tender and tank types, have been built for service in Europe; and as they have proved very suitable for certain classes of traffic, a detailed description of some of them may be of interest.

The former, or tender class, is used principally for long and heavy haulage on main lines with heavy gradients and sharp curves; the latter, or tank class, for the same sort of traffic in mountainous districts where both gradients and curves are exceptionally severe and of frequent occurrence. The problem of economical haulage on such lines presents very great difficulties, and has

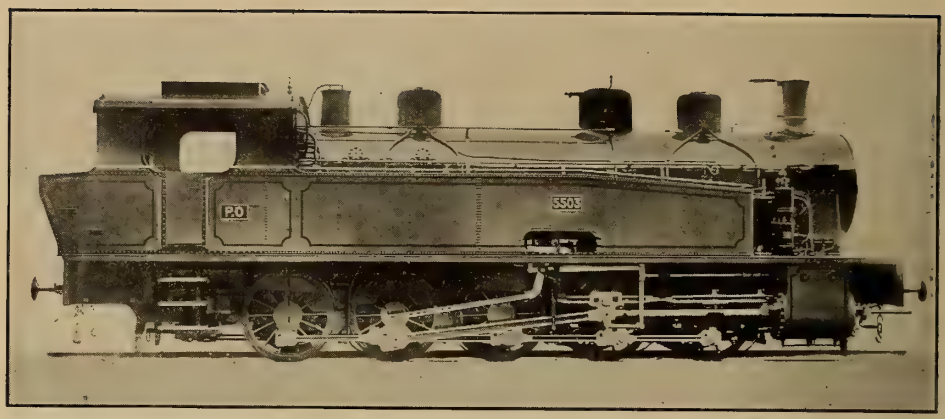


FIG. 2.—TWO-CYLINDER SIMPLE 0-10-0 TANK ENGINE WITH SCHMIDT SUPERHEATER FOR THE SOUTHERN RAILWAY OF FRANCE AND THE PARIS-ORLEANS RAILWAY BY THE BERLIN ENGINE-BUILDING COMPANY

led in the past to designs of engines most of which were complicated and expensive in first cost and maintenance, and some of which could only be classed as "freaks."

The adoption of the Gölsdorf system of axle arranged with considerable side-play in their bearings, either in its original or modified form, has allowed the combination of the above hill-climbing and curve-running qualities with the simplicity of the common locomotive.

The original method was to fix the second and fourth coupled axles and allow a considerable side-play in each direction, generally about 26 mm., or 1 inch, to the first, third and fifth coupled axles. The coupling rod crank-pins of these axles are, consequently, made with total length equal to the length of their bushes plus 2 inches. This arrangement involves driving on to the fourth coupled axle.

On an engine designed on these lines for the Prussian State Railways, the coupled wheelbase being 19 feet 3/8 inch and the fixed coupled wheelbase—i. e., between centres—of second and fourth axles being 9 feet 6 3-16 inches, when standing on a curve of 655 feet radius the lateral deflection of first, third and fifth coupled axles has been found to be about 15-16 inch to the right, 19-32 inch to the left and 5/8 inch to the right hand of the longitudinal centre-line of the engine, and the engine will actually traverse curves of 327 feet radius with ease.

Actual trials have proved this type of engine capable of running smoothly along straight track at speeds of more than 37 miles per hour.

The necessity of using the fourth coupled axle as driving axle involves a great length between this axle centre and the cylinders. To avoid an extremely long connecting-rod it has been necessary to adopt an unusually long piston-rod. In nearly all engines of this type an intermediate, bushed, piston-rod guide has been interposed between the cylinder stuffing-box and the crosshead. This hardly commends itself to the writer as being a desirable arrangement if it is possible to avoid it. It is interesting to note, therefore, that in some of the later designs of ten-wheels-coupled engines this wheel arrangement has been modified. The middle axle has been utilized as driving axle, which, together with the second and fourth axles, has journals without side-play. To give the necessary flexibility to the wheelbase, the first and fifth axles have side-play, as in the original Gölsdorf arrangement, and the driving wheel tire is made with a much thinner flange than the other tires, or in some cases is made flangeless. The coupling-rod

crank-pins of the first and fifth axles have side-play, as before, or in some cases the first and last sections of the coupling-rods are hinged vertically to the adjoining sections and have spherical bearings on the pins.

Actual trials of a Prussian State 0-10-0 engine, Schmidt smoke-tube superheater, the fourth axle being the driving axle, have given the following results: Arnstadt to Suhl. Distance 26 miles, including sixty-four curves of from 1,150 to 4,600 feet, averaging, say, 1,650 feet radius; four long gradients of 1:50. Summit at Oberhof, 18.8 miles from Arnstadt, and rising 1,180 feet on the way, = average up gradient of 1:83.5; thence falling to Suhl, 7.2 miles from and 700 feet below Oberhof, = average down gradient of 1:54. Train of thirty-one wagons = 64 axles. Engine and train = 74 + 507 =581 tonnes = 572 English tons.

Average speed, Arnstadt to Oberhof, 13.1 miles per hour, excluding two stops.

Average speed, Oberhof to Suhl, 13.5 miles per hour, regulator shut most of the time and engine "coasting." Return train, 35 wagons = 72 axles. Engine and train = 74 + 468 = 542 tonnes = 534 English tons.

Average speed, Suhl to Oberhof, 11.1 miles per hour, excluding one stop.

On several occasions during the journey practically 1,000 horse-power were developed and a maximum calculated tractive effort of more than 14 tons. The temperature of the superheated steam in the valve chest varied from about 300 degrees C. ten minutes after starting to a maximum of 350 degrees C. The lowest boiler pressure recorded on rising gradients was over 170 pounds per square inch.

Probestelle to Taubenbach, 9.07 miles, including sixty curves, forty having a radius of 656 feet and two a radius of 580 feet, and none having less than 1,150 feet radius; five gradients of 1:30 and an average gradient of 1:44.5 from start to finish, Taubenbach being 1,075 feet above Probestelle. Train of 16 wagons = 33 axles, engine and train = 74 + 287 = 361 tonnes, or 357 English tons.

Average speed, start to finish, 10.67 miles per hour, excluding one stop.

Average boiler pressure during the trial, excepting a three-minute drop to 168 pounds, was 175 pounds per square inch. After getting fairly to work the temperature of the steam in the valve chest averaged about 325 degrees C.

The success achieved by these 0-10-0 tank engines, as built by the Berlin Engine-building Company for the Prussian State Railways, has led

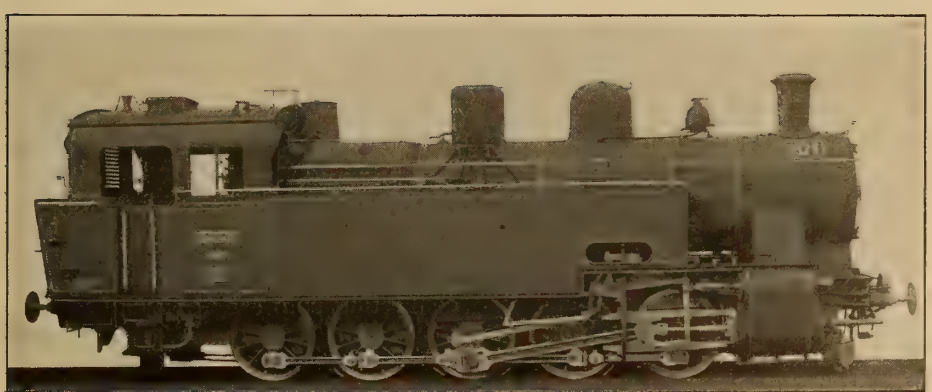


FIG. 3.—TWO-CYLINDER SIMPLE 0-10-0 TANK ENGINE WITH SCHMIDT SUPERHEATER, BUILT FOR THE SAXON STATE RAILWAYS BY THE SAXON ENGINE WORKS, CHEMNITZ

to their adoption by both the Paris-Orleans and the Southern Railway of France for service under similar conditions.

Several recent designs of 0-10-0 engines are illustrated, and after the general description given above there is not much need for further remarks concerning them; but a few points may be noted especially, and these, together with the tabulated list of dimensions, etc., will give a good idea of the type.

Fig. 1 represents the latest type of 0-10-0 for the Prussian State Railways, and is practically the same engine which underwent the trials detailed above, excepting that this latest type drives on to the middle axle.

The main frames are only 25-32 inch thick, this being compensated for by a water tank being built up between the frames of plates about ¼ inch thick. This is a very common practice on these lines and several others on the Continent, and commends itself to the writer as being a good way of utilizing space otherwise wasted, and at the same time stiffening up the frames.

Fig. 2 represents 0-10-0 engines built for both the French Southern and also the Paris-Orleans Railway. Main frames are 1 3-16 inches thick, and also have water tanks built up between them. These engines were designed and built by the Berlin Engine-Building Company.

Fig. 3 represents an engine designed by the Saxon Engine Works, formerly R. Hartmann, of Chemnitz, for hauling heavy trains on lines having gradients up to 1:40, on the Saxon State Railways, with speeds of 25 miles per hour. The same firm also designed the two-cylinder compound engine shown in Fig. 7, for similar traffic. The former have the Schmidt smoke-tube superheater; the latter are fitted with an intermediate superheater or steam dryer, consisting of twenty-five snake-shaped steel tubes which have their ends expanded into two cast-steel headers, one on each side of the smoke-box. The chimney is placed just in front of the tube-plate, and these tubes occupy the whole of the space in the extended smoke-box in front of blast pipe down to the level of second row of tubes. The steam passes from the high-pressure cylinder to one header, through these tubes into the other header, and thence to the low-pressure cylinder. "Lindner" starting gear and by-pass cocks in passage connecting both ends of cylinders, for use when "coasting" and stopping, are fitted.

FIG. 4.—TWO-CYLINDER SIMPLE 0-10-0 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, BUILT FOR THE SWEDISH STATES RAILWAYS BY MESSRS. NYDQVIST & HOLM, TROLLHÄTTAN

Fig. 4 shows a very powerful engine designed by Messrs. Nydqvist & Holm, Trollhättan, Sweden, for

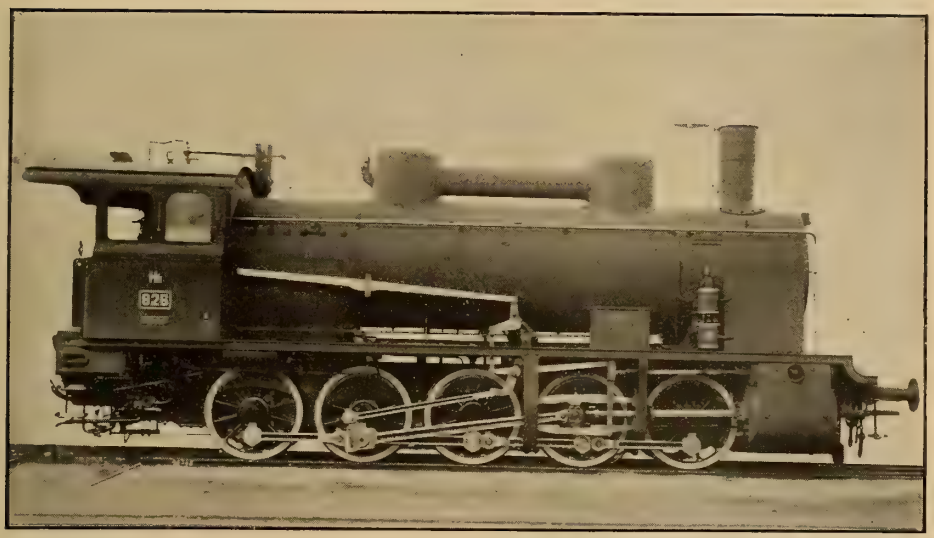


FIG. 5.—TWO-CYLINDER COMPOUND 0-10-0 ENGINE FOR THE WURTEMBERG STATE RAILWAYS BY THE ESSLINGEN ENGINE WORKS, WURTEMBERG

hauling heavy mineral trains on the Kiruna-Riksgränden section of the Swedish State Railways. Trials have shown these engines capable of hauling, with 4.5 per cent. cut-off, a total train load of 1,430 tons along this section, which has 1 :100 gradients—work formerly done by eight-wheels-coupled engines with a banking engine to assist.

The main frames of the engine are steel castings 4.33 inches thick, "Bar" design, made in two lengths, with bolted and keyed joint between third and fourth axles, and were cast by the engine-builders. Cross-stretchers, boiler saddles, dry-box and frame details generally are steel castings.

The engines are fitted with electric lights driven by De Laval steam turbines.

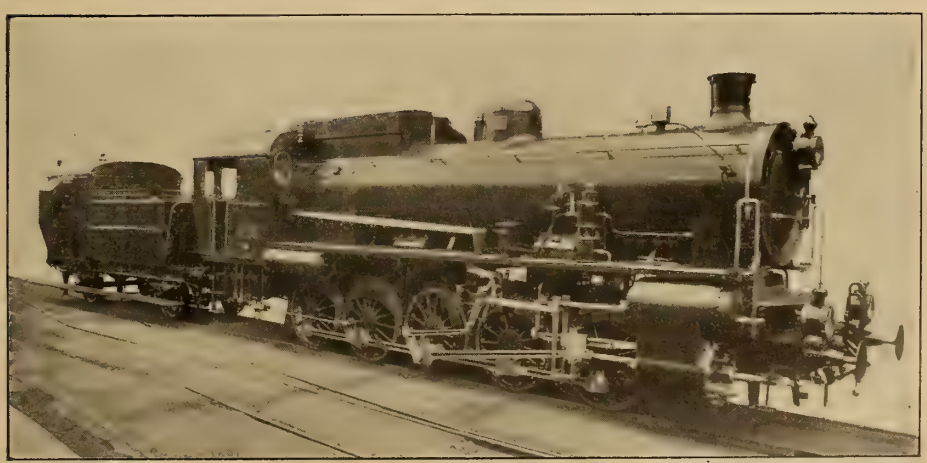


FIG. 5A.—FOUR-CYLINDER BALANCED COMPOUND 0-10-0 ENGINE AND TENDER FOR THE ITALIAN STATE RAILWAYS, BY ERNESTO BREDA, MILAN

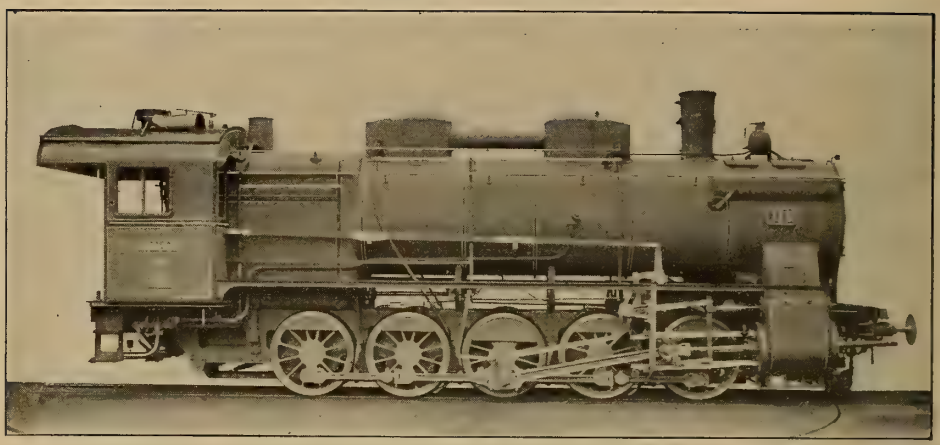


FIG. 7.—TWO-CYLINDER COMPOUND 0-10-0 COMPOUND ENGINE WITH RECEIVER SUPERHEATER FOR THE SAXON STATE RAILWAYS, BY THE SAXON ENGINE WORKS, CHEMNITZ

The first and fifth axles have 25-32-inch side-play in both directions.

The engine shown in Fig. 5—a two-cylinder compound, working on the "Gölsdorf" system—was designed by the Esslingen Engine Works, Esslingen, Württemberg, for the Württemberg State Railways, to satisfy the following conditions: To pass easily round curves of 590 feet radius and run steadily at 31 miles per hour along the straight. To pull a load behind drawbar of 675 tons at 12.5 miles per hour and 720 tons at 11.25 miles per hour up a gradient of 1:100 curved to radius of 900 feet, without unduly pressing the boiler. The axle load is limited to 14.75 tons. The Württemberg State Railways are also adopting the Schmidt smoke-tube superheater for a 0-10-0 engine.

The engines designed by the firm of A. Borsig for the Servian State Railways, shown in Fig. 6, have proved themselves to be good haulers and steady runners on difficult sections of line containing long gradients of 1:61.5 and curves of 557 feet radius. They will actually traverse curves of 295 feet radius if necessary. The frames are 1.34 inches thick, stiffened with a fore-and-aft plate stay of .59 inch thick. The Gölsdorf system of compounding is adopted, in which the low-pressure slide valve, when in full gear, uncovers ports communicating with a live-steam supply, admitting it, throttled down, to the low-pressure valve chest. On linking up the valve gear, after starting, these ports are no longer uncovered by the movement of the valve. The general simplicity of the whole design of the engine is noticeable.

Fig. 5A shows an engine designed for working on mountainous sections of the Italian State Railways, including gradients as severe as 1:38.4.

The tender, carrying the water, is built with ordinary buffers at each end, and both feed-water and all other connections are duplicated, both back and front of engine and tender. Coal is carried in the bunker, which can be seen in front of the cab on top of the boiler, and which is continued down to the foot-plate level on the left-hand side. The cylinder arrangement is an unusual one, though several classes on the Italian Railways have it. The two low-pressure cylinders, with their valve chest, common to both, and half-saddle, are placed on the right-hand side; and similarly the two high-pressure cylinders, common valve chest and half-saddle, are placed on the left-hand side of the engine, and are joined by their flanges a little to the left of the longitudinal centre-

line of the engine. Piston valves, with independently-controlled Walschaert gear, are used. All four cylinders drive to the third coupled axle, the centre-lines of the cylinders being inclined at an angle of 8 degrees to allow of this, while the second coupled axle is somewhat cranked, to clear the inside connecting-rods. The outside cylinders are practically horizontal. A "Z" crank axle is used, the "throws" being at 90 degrees and the outside "throws" at about 180 degrees to these, allowance being made for the angle between the cylinders, the arrangement being, therefore, a balanced compound. To enable the one valve chest to supply steam to two high-pressure cylinders working cranks at nearly 180 degrees, a simple piston valve is used, but the steam passages to the two cylinders are crossed. For the low-pressure cylinders the same end is attained by using a piston valve having four heads. The two middle ones control the steam passages to the outside low-pressure cylinder, which has outside admission, and the two outer ones controlling those of the inside low-pressure cylinder, which has inside admission. The receiver steam is introduced at points between the first and second and between the third and fourth heads. Starting is effected by admitting live steam through a pipe connected to the regulator and so arranged that when the latter is slightly opened the steam passes through this pipe to a chamber which is a prolongation of the high-pressure valve chest. In this chamber is a prolongation of the high-pressure valve spindle, which is so formed as to act as a slide valve admitting the live steam, throttled en route to the receiver. On further opening the regulator this steam supply is cut off.

The whole cylinder arrangement is ingenious, but complicated. The opinions of the pattern-makers and cylinder moulders concerned would doubtless be of interest, but they are not on record.

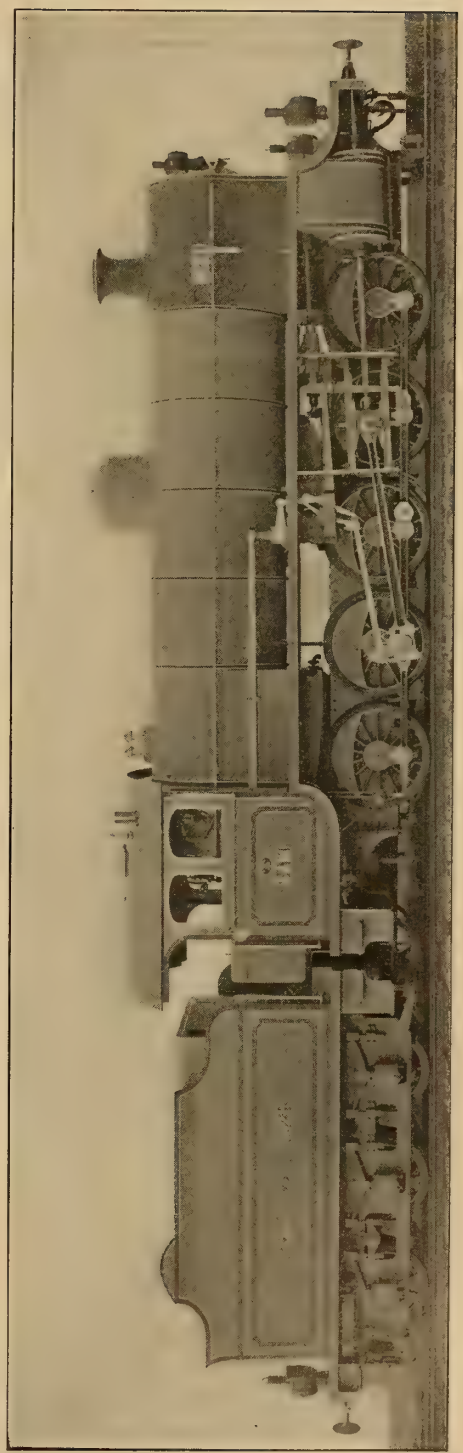


FIG. 6.—TWO-CYLINDER COMPOUND 0-10-0 ENGINE AND TENDER CONSTRUCTED FOR THE SERVIAN STATE RAILWAYS BY A. BORSIG, TEGEL, BERLIN

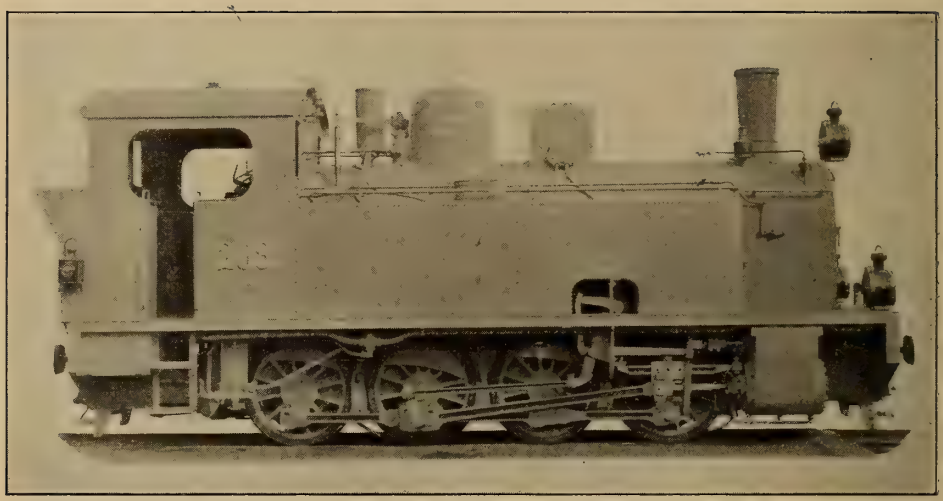


FIG. 8.—TWO-CYLINDER SIMPLE 0-8-0 TANK GOODS ENGINE, NARROW GAUGE, BUILT FOR THE ITALIAN STATE RAILWAYS BY THE BERLIN ENGINE-BUILDING COMPANY

Flexibility of wheelbase is attained by allowing about 25-32 inch side-play in each direction to the first and fifth axles, the corresponding coupling-rod crank-pins being made with spherical journals. The driving-wheel tires are flangeless. All the axles are compensated in one system.

These engines have been built both by J. A. Maffei, of Munich, and by Ernesto Breda, of Milan, the view showing an engine by the latter firm.

EIGHT-WHEEL-COUPLED GOODS ENGINES

The engine shown in Fig. 8 is an interesting example of a powerful tank engine for narrow-gauge lines. This was constructed by the Berlin Engine-Building Company for the Sicilian lines of the Italian State Railways. The gauge is only 950 mm., or 3 feet 1 13-32 inches, and the total loaded weight is 47.3 tons, an average of 11.82 tons per axle. Maximum tractive force calculated at 75 per cent. of boiler pressure, which is 200 pounds per square inch, is 8.1 tons. The main frames are 1 inch thick and strengthened by having a water tank built in between.

A powerful goods engine, designed and built for the Anatolian Railway Company by Messrs. Henschel & Son, Cassel, is shown in Fig. 9. Fitted with Schmidt smoke-tube superheater and ample grate area and heating surfaces, and having a maximum tractive force of 14.75 tons at 75 per cent. of boiler pressure, this engine is capable of hauling big loads up long gradients. The axle-load is limited to 13.3 tons on some sections of the lines, but on gradients and reconstructed sections the load on the drivers can be increased from 54.25 tons to 58.5 tons by fitting up from the tender a tank built up between the engine frames.

The leading axle is radial, and the second and fourth coupled axles have ½ inch play to either side, enabling the engine to run easily through sharp curves.

Fig. 10 shows a 0-8-0 two-cylinder goods engine and tender built by Messrs. Nydqvist & Holm for the Bergslagernas Railways of Sweden. The drive is to the second axle, and the valves of the cylinders, which are behind the frame, are worked by Walschaert gear, also arranged between the frames. The superheater is Schmidt's patent, which this firm has applied to nearly 100 engines up to the present date.

The four-cylinder, divided and balanced compound 2-8-0 goods engine

and tender shown in Fig. 11, built by the Swiss Locomotive & Engine-building Company, of Winterthur, for the State Railways of Switzerland, has high-pressure piston valves and low-pressure flat balanced valves of the Trick or Allen type, both pairs driven from a return crank fixed on the third coupled axle, which is the driving axle for the outside low-pressure cylinders. The high-pressure valves are driven from the top end of the lap-and-lead lever through a rock-shaft carried in brackets bolted to the cylinders. This arrangement necessitates inside admission to the high-pressure and outside admission to the low-pressure valves. The inside high-pressure cylinders drive to the second coupled axle. The cylinder dimensions are: 14.57 × 23.62 inches and 23.62 × 25.2 inches, giving a cylinder volume ratio of 2.8:1. The leading axle is radial, and the fourth coupled axle has side play, giving a fixed engine wheelbase of 10 feet 7 15-16 inches. The radial and first coupled, and also the second, third and fourth coupled axles, are compensated. The starting gear is worked from the reversing rod. These engines were designed for maximum speeds of 40 miles per hour and a maximum continuous power of 1,050 horse-power and to take loads of 200 tons up grades of 1:38.5 at 15 miles per hour. The maximum tractive force is 11.9 tons.

Fig. 12 shows a powerful two-cylinder compound 2-8-0 goods engine of the Italian State Railways. Instructions as to the general requirements of the traffic and road were given out by the State authorities in Florence, and the actual design was entrusted to Messrs. Henschel & Son, of Cassel, and an order for fifty-nine engines placed with them. So successful have these first engines proved themselves that a further lot of fifty-one were ordered, making a total of 110 of this class at work in 1908. The eight-thousandth engine built by this firm is included in this batch.

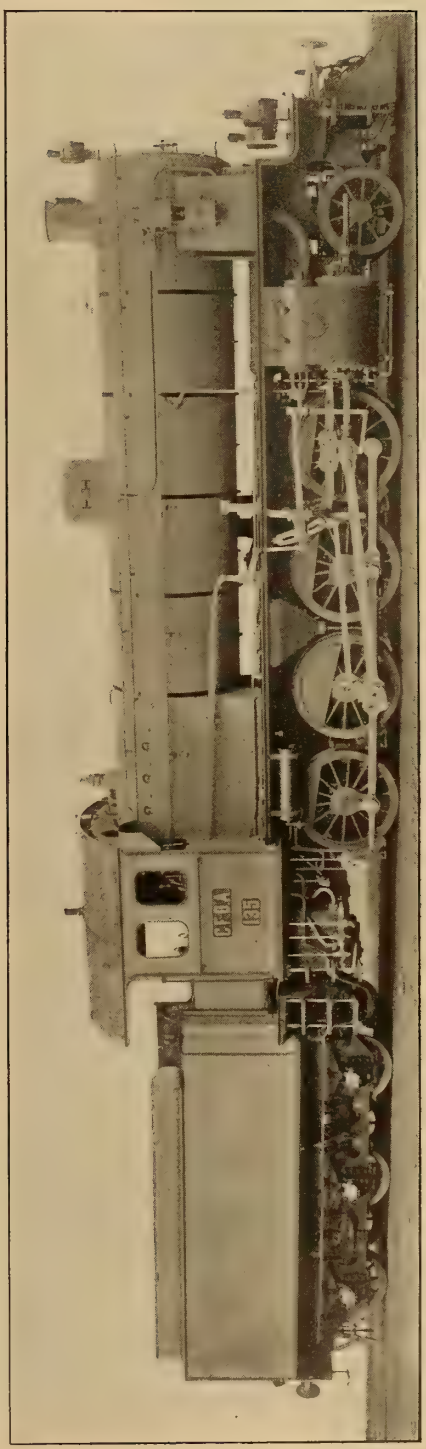


FIG. 9.—TWO-CYLINDER 2-8-0 GOODS ENGINE AND TENDER WITH SCHMIDT SUPERHEATER FOR THE ANATOLIAN RAILWAYS, BUILT BY MESSRS. HENSCHEL & SON, CASSEL

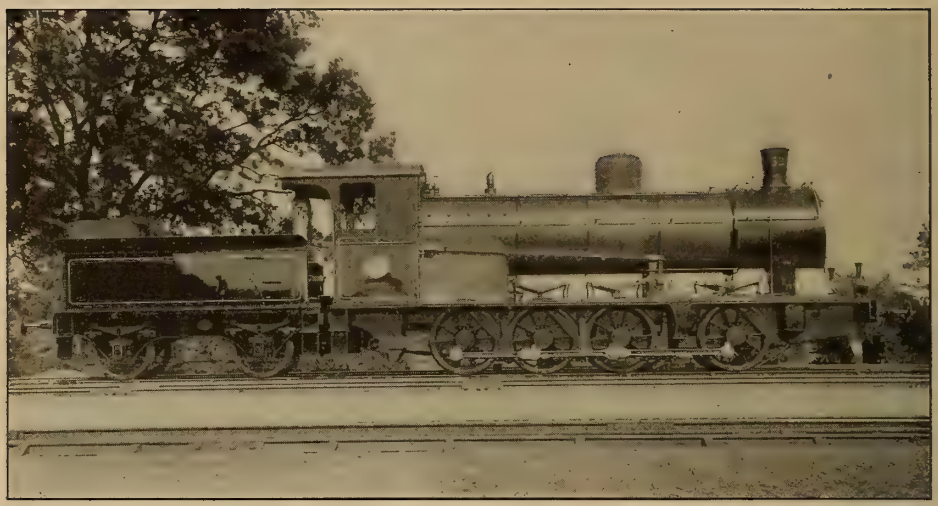


FIG. 10.—TWO-CYLINDER SIMPLE 0-8-0 ENGINE WITH SCHMIDT SUPERHEATER, BUILT FOR BERGSLAGERNAS RAILWAYS, SWEDEN, BY MESSRS. NYDQVIST & HOLM, TROLLHÄTTAN

In order to attain easy running through sharp curves, the rigid wheelbase is reduced to 9 feet 10 inches by fixing only the second, third and fourth coupled axles. The leading axle and the first coupled are combined in a "Zara" bogie, which is a modification of the Krauss bogie, allowing not only for turning round a pivot, but also for a traversing movement of the pivot, with respect to the bogie frames, of 25-32 inch to either side of mid-position. This is attained by hanging the lower half of the pivot bearing on four moving links connected to the bogie frames. This side movement is controlled by volute springs. The first coupled axle is carried in axle boxes working between horn blocks fitted to the main frames of the engine, and has 0.79 inch side-play in each direction. It takes its load, transmitted from the engine to the bogie pivot through a small pivot bearing on the top of an underhung transverse plate-spring,

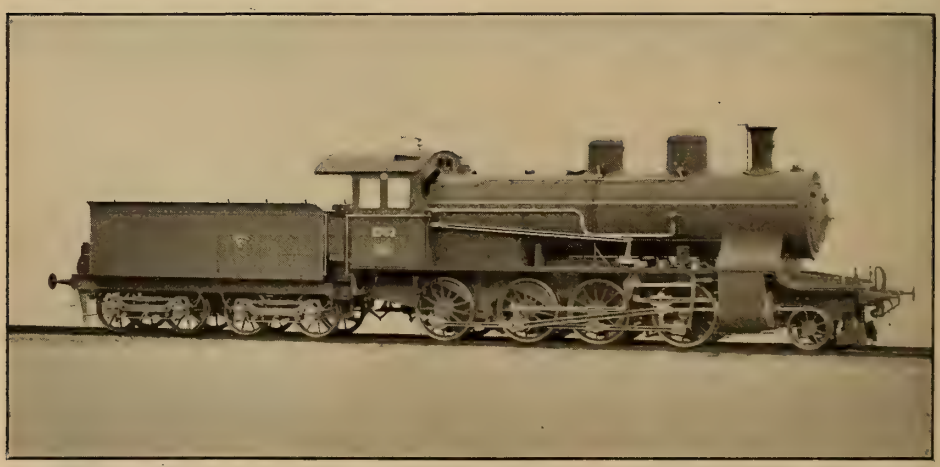


FIG. 11.—FOUR-CYLINDER COMPOUND, DIVIDED AND BALANCED, GOODS ENGINE AND TENDER FOR THE STATE RAILWAYS OF SWITZERLAND BY THE SWISS LOCOMOTIVE AND ENGINE-BUILDING CO., WINTERTHUR

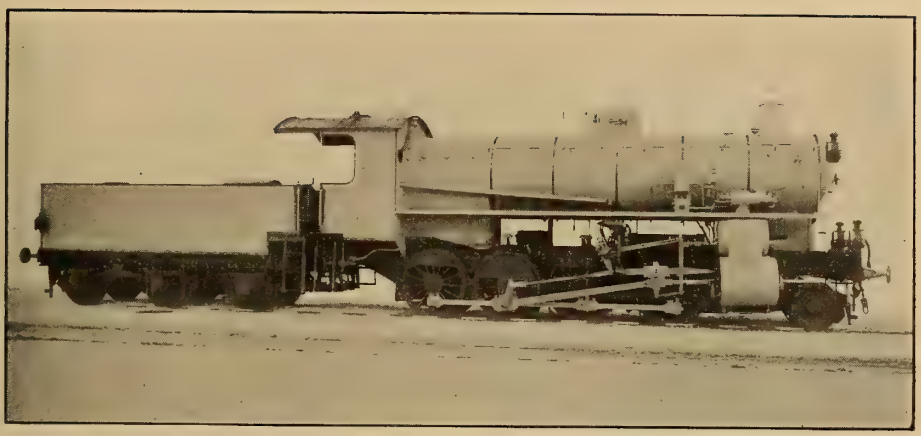


FIG. 12.—TWO-CYLINDER COMPOUND 2-8-0 ENGINE AND TENDER FOR THE ITALIAN STATE RAILWAYS, BY MESSRS. HENSCHEL & SON, CASSEL

whose ends are carried by pins in the axle-box spring links. In case of breakage of this spring, the spring buckle, which is made with projecting flanges at the top, would then rest, by means of these flanges, on the two cross members, also connected to axle-box spring links. The coupling-rod crank-pins of the first coupled axle have spherical journals. The leading axle has ordinary plate springs over each journal. This bogie has its own brake cylinder and gear. The second, third and fourth axles have "Zara" axle boxes, allowing the axles to cant when running over irregularities in the line, whilst the bearings remain bearing evenly on the journals (see Fig. 12A).

The compounding arrangement is of the Von Borries type, the intercepting and starting gear being placed on the low-pressure valve chest, the change over to compound working being automatic when the receiver pressure is high enough.

The piston valves have inside admission, and cut-offs of from 20 to 80 per cent. can be used, that of each cylinder being capable of independent regulation by means of separate reversing rods, one lying behind the

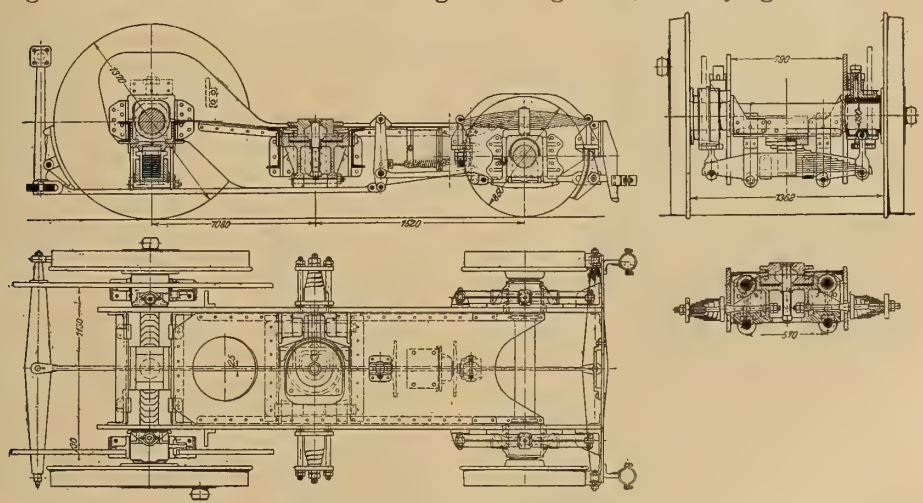


FIG. 12A.—DETAILS OF "ZARA" BOGIE TRUCK

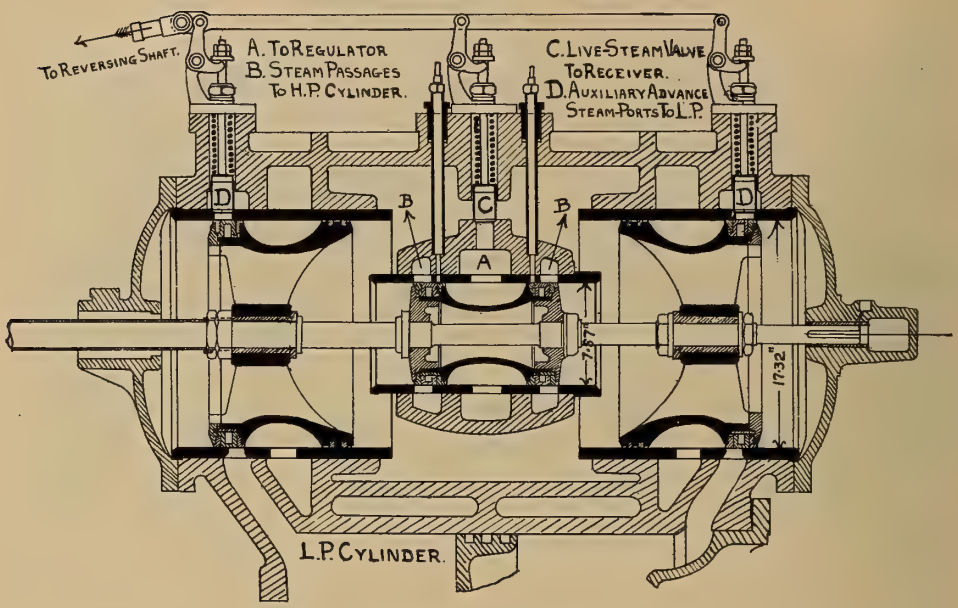


FIG. 12B.—VALVE CHEST FOR ONE HIGH-PRESSURE AND ONE LOW-PRESSURE CYLINDER, SHOWING PISTON VALVES AND STARTING GEAR

other. The two top rows of water-space stays, and also the front and the back vertical row in the side sheets, are of mild steel, the remainder of copper—a very unusual arrangement. A variable, hand-controlled blast-nozzle is fitted.

These engines can haul 170 tons behind the tender up 15.5 miles of gradients of 1:40 to 1:38.5 at 23.6 miles per hour, developing 1,100 horse-power, or .51 horse-power per square foot heating surface, and were designed for a maximum speed of 40 miles per hour on the level.

Fig. 13 shows a powerful four-cylinder 2-8-0 goods engine and tender built by J. A. Maffei, of Munich, for the Baden State Railways, which is fitted with a "steam dryer" of the Pielock type. This consists of a continuation of the boiler-barrel proper, closed in at the front by a second "drum head" tube-plate. The boiler tubes are prolonged between the two tube-plates, and the steam is constrained by baffle plates to circulate in a zig-zag course over the tubes. This arrangement does not allow the steam to attain to the same high temperature as does the "Pielock" superheater proper, built up in the middle of the length of the boiler-barrel, where the flue gases are hotter.

The cylinder dimensions are 15.55 inches and 25.0 in. × 25.2 in. stroke, and drivers are 4 feet 515 inches diameter, and steam pressure 227 pounds per square inch, giving a maximum tractive force of 15 tons. As the weight on coupled axles is 63 tons, this gives a minimum adhesion coefficient of 4.2. Grate area, heating and "steam-drying" surfaces are 40.3, 2,100 and 538 square feet, respectively; from which it will be seen that this is a very powerful engine. The general arrangement is characteristic of this firm's engines. The bar frames give easy access to all moving parts between them and an easy cylinder attachment, and make a strong support at the back end to carry the heavy firebox. Though the total wheelbase of the engine is 24 feet 5.3 inches, by the scheme of side-play in the axles this is reduced to a rigid wheelbase of 10 feet 9.9 inches. The cylinders are

cast in pairs, one inside high-pressure with one outside low-pressure, their common valve chest and the half-saddle on the right hand being bolted up along the longitudinal centre-line of the engine to another similar casting on the left hand. All four cylinders drive on to the third coupled axle, the inside high-pressure being inclined 1:1.15 to clear the front axles, and, also, the cylinder centre-line passes 4.72 inches above the driving-axle centre.

The valve chest, common to one high-pressure and one low-pressure cylinder, contains two piston valves. In the middle of the spindle is mounted the high-pressure valve, 7.87 inches in diameter, which is of the closed variety—i. e., steam cannot pass through its body. The low-pressure valve, 17.32 inches in diameter, consists of two parts or heads, each having two sets of spring rings, enclosing the exhaust between them (Fig 12B).

These two heads are of the open type—i. e., steam can pass through them from end to end. They are fixed on the spindle, one at one side and the other on the opposite side of the high-pressure valve, which, therefore, lies in between them. The high-pressure valve gives inside admission and the exhaust finds its way through the low-pressure valve heads and into the low-pressure cylinder, which has outside admission. The exhaust follows, through the exhaust bridges in the valve heads, and through exhaust pipes—two for each low-pressure cylinder—to the blast pipe.

Starting is effected as follows: As soon as the valve gear, either in forward or backward gear, is in any position giving 70 per cent. cut-off or over, three small valves, covering passages 1.38 inches diameter, are lifted off their seats. The middle one admits steam from the high-pressure cylinder steam supply to the receiver, and the two outside passages open into the low-pressure valve-chest bushings in advance of the or-

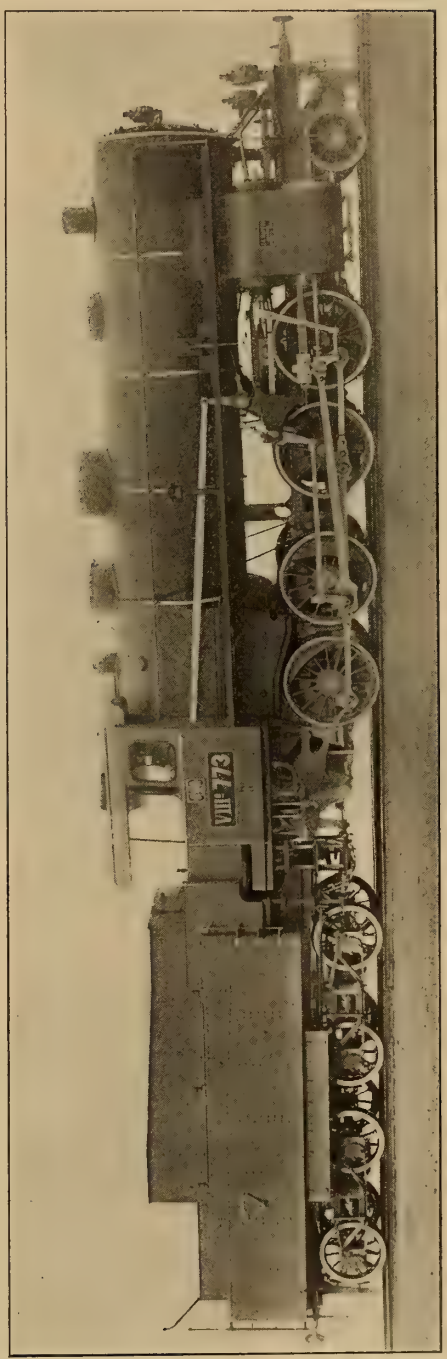


FIG. 13.—FOUR-CYLINDER BALANCED COMPOUND 2-8-0 ENGINE AND TENDER WITH STEAM DRYER, BUILT FOR THE BADEN STATE RAILWAYS BY J. A. MAFFEI, MUNICH

dinary steam ports. This ensures quick filling of the low-pressure cylinders and prompt starting.

From this description it will be seen that only one set of valve gear is necessary for both high-pressure and low-pressure cylinders, thus saving actual working parts. The cylinder castings, however, are somewhat complicated as a result; but, compared to many designs to be seen nowadays in the workshops, not unduly so.

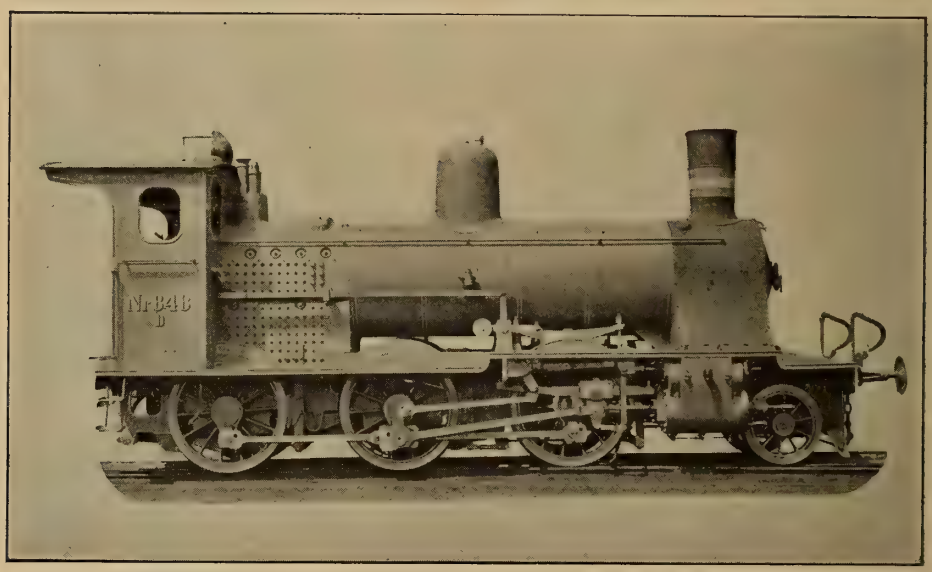


FIG. 13A.—TWO-CYLINDER SIMPLE 2-6-0 GOODS ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, BUILT FOR THE DANISH STATE RAILWAYS BY THE BERLIN ENGINE-BUILDING COMPANY

SIX-WHEEL COUPLED GOODS ENGINES

Fig. 13A shows a 2-6-0 goods engine and tender for the Danish State Railways, fitted with Schmidt superheater. This is a comparatively small and light engine, designed to suit conditions of service and permanent way on these railways. Comparison between the running of these engines and that of already existing types of "wet steam" engines, and investigation into the behaviour of highly superheated steam and problems connected with its application to locomotive work, are being carried on by both the mechanical and technical departments of these railways under the direction of Mr. Busse, the locomotive superintendent, and the results will no doubt be of great interest when completed. The details of these engines conform to the usual practice of Schmidt's system for superheated steam. Dimensions are given in the tabulated list. These engines were built by the Berlin Engine-building Company during 1909.

SIX-WHEEL COUPLED PASSENGER ENGINES OF THE "PACIFIC" TYPE

In France, as in other countries, the locomotive departments of the railways have found that the appetites of their brethren of the traffic department for heavier trains and quicker speeds have merely increased from time to time as the result of the assimilation of each new design presented to them, and the cry is always for more.

After extensive trials, the officials of the Paris-Orleans Railway came to the conclusion that their four-cylinder compound 2-6-0 and 2-4-0 types, put into service in 1903, were no longer able to satisfy these in-

FIG. 14.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-2 ENGINE FOR THE PARIS-ORLEANS RAILWAY, BY THE HANNOVER ENGINE-BUILDING COMPANY

satiable demands, and the "Pacific" type, Fig. 14, was got out in consequence and put to work in 1907. This design was adopted in order to accommodate the increased boiler dimensions considered necessary to cope with the traffic.

The cylinders are 15.35 inches and 25.2 inches by 25.6 inches stroke, the pressure being 228 pounds per square inch and the drivers 6 feet 0.84 inches diameter, giving a tractive force of 11.3 tons. The grate area of 46 square feet and the heating surface of 2,765 square feet guarantee an ample supply of steam. The boiler is 19 feet 4.3 inches between tube plates and 5 feet 6.14 inches diameter. The high-pressure cylinders, placed outside the frames, have piston valves, and drive the second coupled axle; the low-pressure cylinders,

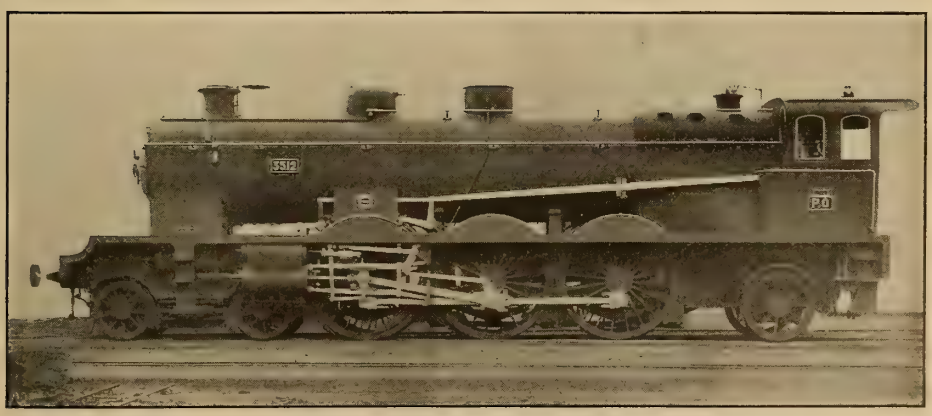


FIG. 15.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-2 ENGINE FOR THE PARIS-ORLEANS RAILWAY, BY THE SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES, BELFORT

placed inside the frames, have flat slide valves, and drive the first coupled axle. In actual service one of these engines has taken a train of 360 tons between Paris and Les Aubrais, a section including the climb at Etampes, at a mean speed of 54.7 miles per hour, and between Les Aubrais and St. Pierre-des-Corps at a mean speed of 59 miles per hour.

In trials made between Brive and Limoges, a distance of 60 miles, involving very heavy climbing work up 1:100 gradients, with ordinary trains averaging 374 tons, a mean speed of 35.8 miles per hour was maintained, with average indicated horse-power of 1,240. The consumption of coal and water, respectively, per indicated horse-power-hour of 4.04 pounds and 29.2 pounds, gave an evaporation of 7.25 pounds water per pound coal consumed, the latter being a mixture of half-and-half Welsh and briquettes. Taking a train of 410 tons between Atlassac and La Porcherie, a distance of 25 miles of practically continuous up-hill, averaging 1:121 for the whole distance, the average speed was 35.7 miles per hour and the average indicated horse-power and draw-bar horse-power 1,460 and 1,045, respectively. A maximum speed of 77.6 miles per hour is allowable with this type. These engines are shown in Fig. 14, taken from a photograph of one of the series built by the Hannover Engine-Building Company, formerly G. Egestorff.

Fig. 15 shows a very similar type which was derived from the above engines, having the same cylinders and boiler, but larger driving wheels, these being 6 feet 4.77 inches diameter. This has involved alteration in the wheelbase dimensions and a very slight increase in total length and weight. The maximum tractive effort in this case is 10.75 tons, and the engines were built by the Société Alsacienne de Constructions Mécaniques at their Belfort works in 1909.

In both these engines the manner in which a deep firebox, combined with very large grate area, has been attained and at the same time placed well forward along the frames, by narrowing in the front end of the box to go between the frame, is noteworthy. The class with 6-feet 0.84-inch driving wheels is being built with the same general dimensions, excepting an increase of the high-pressure cylinder diameter to 16.54 inches, as a superheated steam engine, with about 675 square feet of superheating surface, retaining the boiler pressure of 228 pounds per square inch. A comparison of the performances of the two classes, when trials have been made, will be of great interest.

Similar reasons to those which compelled the Paris-Orleans Railway to design the engine just described have induced the locomotive department of the Western Railway of France to design and build heavy engines of the "Pacific" type, one of which, built at the Sotteville works of the company, Rouen, is shown in Fig. 20. Having decided that it was necessary to adopt the wide type of firebox, it was incumbent to abandon the 4-6-0 class previously doing the heavy express work on the Paris-Havre, Paris-Brest and Paris-Cherbourg routes and adopt the 4-6-2 arrangement of wheelbase.

In order, however, to reduce length and weight as much as possible, the wheels have been packed together as closely as could be arranged. The throat and back plates of the firebox are given a big "rake" to shorten the boiler-barrel. This may be compared to the method of narrowing in the front end of the firebox in the two Paris-Orleans engines just described to attain the same result. The outside low-pressure cylinders drive the second coupled axle and the inside high-pressure cylinders drive the first coupled axle, the outside crank-pin being set at 180 degrees to the corresponding inside crank-pin. On account of the main frames being cut away to allow clearance to the bogie wheels, the high-pressure cylinders,

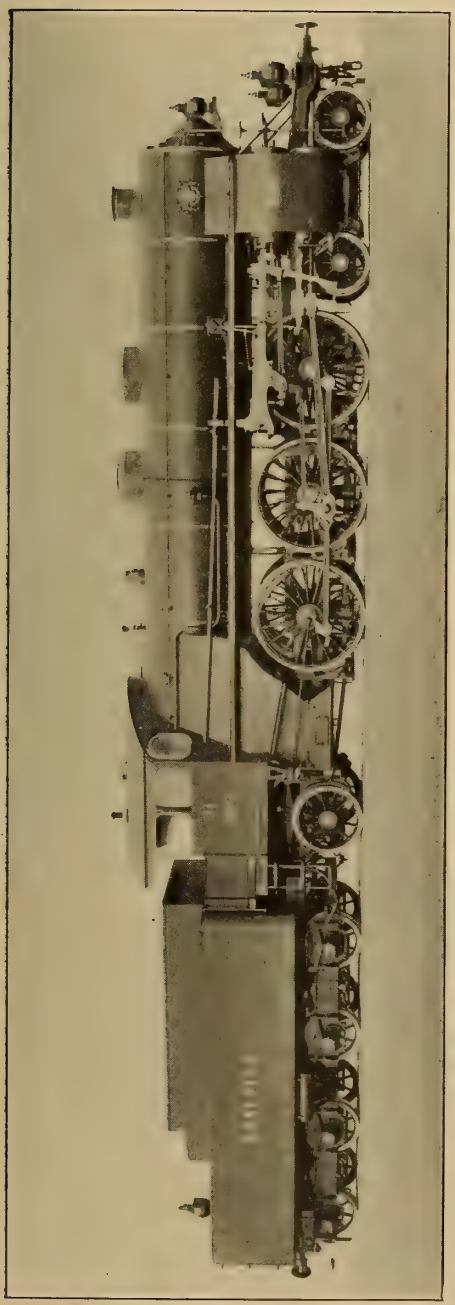


FIG. 16.—FOUR-CYLINDER COMPOUND BALANCED 4-6-2 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER FOR THE BAVARIAN STATE RAILWAYS, BY J. A. MAFFEI, MUNICH

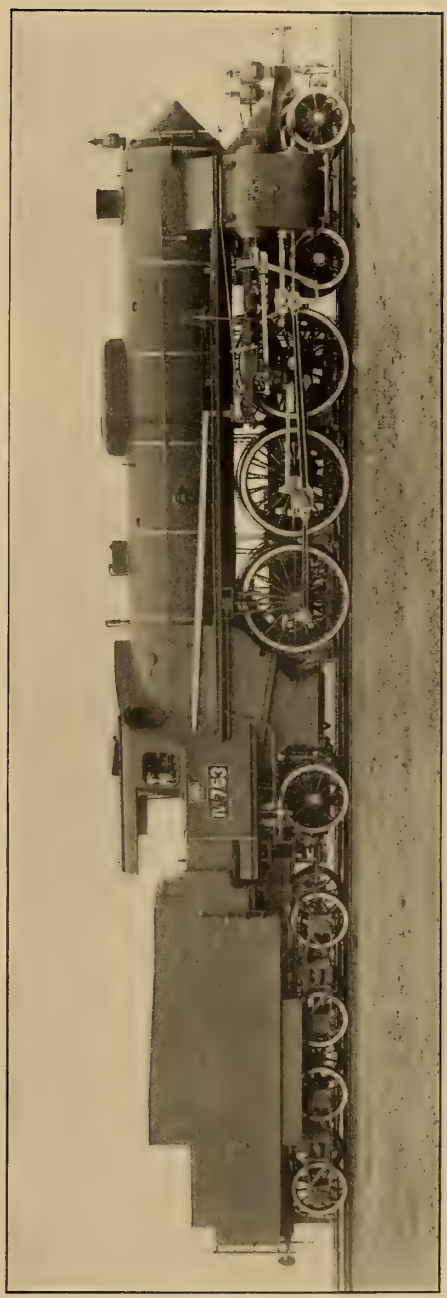


FIG. 17.—FOUR-CYLINDER BALANCED COMPOUND 4-6-2 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, BUILT FOR THE BADEN STATE RAILWAYS BY J. A. MAFFEI, MUNICH

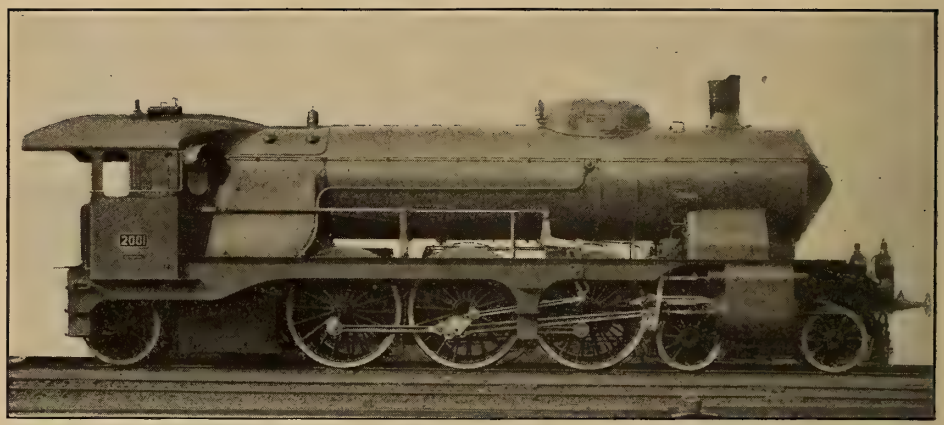


FIG. 18.—FOUR-CYLINDER COMPOUND 4-6-2 ENGINE WITH SCHMIDT SUPERHEATER, FOR THE STATE RAILWAYS OF WURTEMBERG, BY THE ESSLINGEN ENGINE WORKS

cast in one piece with their piston valve chests and De Glehn type intercepting valve chest, cannot be fastened direct to them. They are, therefore, bolted to a heavy frame stay and saddle casting, which is placed between the low-pressure cylinders at their rear ends in an overhanging position; in addition, they are bolted to the floor of the smoke-box. A cast-steel frame-stay, which is also carried out over the frames, supports both the rear ends of the high-pressure slide-bars, and by means of a longitudinal bracket secured to the low-pressure cylinders at its front end and to the frame-stay at its middle, the low-pressure slide-bars, In addition, it forms a support for the independent reversing shafts of high-pressure and low-pressure valve gear and the high-pressure expansion links. The low-pressure expansion links are carried by the same longitudinal bracket that supports the low-pressure slide-bars. The arrangement of the Walschaert valve motion is very unusual. Considerations of space led to the abandoning of the usual method of driving the lap-and-lead levers off the crosshead. The outer return crank-pin seen in the photograph drives the low-pressure lever direct, and the high-pressure lever, which is inverted, through the rocking shaft, to be seen between first and second coupled wheels. The inner return crank-pin drives the low-pressure expansion link direct, and the high-pressure through a rocking lever actuating a shaft which is an extension of the high-pressure expansion link pivot. All valves are piston valves, with inside admission. The inner firebox crown-sheet is sloped to the rear, and commendably large water spaces, 4¾ inches, have been adopted, and a very wide fire-door.

The smoke-box has the enormous length of 10 feet 1½ inches inside—much greater than has been found necessary in the case of the Pacific type engines of similar dimensions.

The coupled axles are loaded through plate springs, overhung, and the spring gear of each side of the engine is joined up by equalizing levers, which also connect to the springs of the Bissel truck placed under the firebox. This truck is so constructed as to allow displacement about three axes at right angles, the whole system allowing the wheels to accommodate themselves readily to inequalities of the road without shock to the engine and to take curves easily.

Fig. 16 shows a Pacific type four-cylinder, balanced compound engine with Schmidt superheater, built for the Bavarian State Railways by the

firm of Maffei, Munich. With cylinders 16.72 inches by 24 inches and 25.6 inches by 26.4 inches and boiler pressure of 213 pounds per square inch, and coupled wheels 6 feet 1.62 inches diameter, this engine has a maximum tractive force of 11.16 tons.

Fig. 17 shows a very similar engine, also with Schmidt superheater, built by the same firm for the State Railways of Baden. This differs from the Bavarian engine in having coupled wheels of 5 feet 10.8 inches diameter, which, with a higher boiler pressure of 228 pounds per square inch, but with the same dimensions of cylinders, gives a maximum tractive effort of 12.35 tons. With grate area, heating surface and superheating surface respectively of 48.4, 2,348 and 538 square feet for the Bavarian, and 48.4, 2,246 and 538 square feet for the Baden engine, it will be recognized at once that these are two extremely powerful engines.

A description of the Baden engine in some detail may be of interest, the general arrangement of the Bavarian engine being very similar.

As is usual with four-cylinder compound built by this firm, the high-pressure cylinders are placed between the frame and the low-pressure outside. All four drive on to the middle coupled axle. To enable this to be done, the high-pressure cylinders have a considerable incline, and their centre-lines pass 4.72 inches above the driving axle centre-line. The valves are all piston valves, the low-pressure being driven direct from an outside return crank-pin and the high-pressure being driven off the same gear through a rocking shaft. The high-pressure valves have single steam ports and inside admission, the low-pressure having double ports and outside admission.

For starting purposes the pressures on both sides of the high-pressure pistons are equalized by means of cocks worked off the reversing gear when the latter is in full gear and throttled boiler steam admitted at the same time to the low-pressure cylinders. Also, when the cut-off reaches a point over 70 per cent., live steam is admitted to the low-pressure cylinder through special entrance ports, in a manner similar to that described in connection with Fig. 13. Connecting-rods and driving axle are of nickel-steel, and all axles have the cores bored out. The three-coupled axles and the trailing axle, which is

FIG. 19.—FOUR-CYLINDER BALANCED DIVIDED COMPOUND 4-6-2 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, FOR THE IMPERIAL RAILWAYS OF ALSACE-LORRAINE, BY THE SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES, GRAFENSTADEN

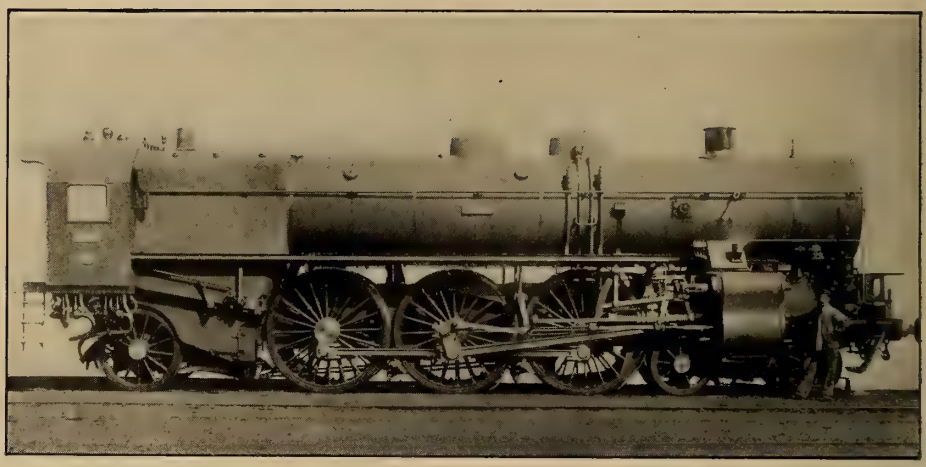


FIG. 20.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-2 ENGINE AND TENDER FOR THE WESTERN RAILWAY OF FRANCE, AND BUILT AT THE COMPANY'S WORKS AT SOTTEVILLE, ROUEN

"radial," are compensated, and by an arrangement of slots in the connecting bell-crank levers, in which die-blocks and pins which are coupled to a small steam cylinder can work to and fro, the leverage of the compensating gear is varied, and an extra load of about 3 tons can be thrown on to the coupled axles when considered necessary. The main frames are of mild steel of the "Bar" type, and are in one length from end to end. The bogie and trailing radial axle have side-play in either direction of 2.95 inches and 2.42 inches, respectively; 19.7 tons of water and 6.9 tons of coal are carried on the tender.

These engines were designed for the purpose of hauling heavy express trains on the Mannheim and Heidelberg-Basel service, involving medium gradients, and also on the very heavily graded Offenberg-Triberg-Konstanz line. They have taken trains of 52 axles = 450 tons over the 160 miles between Mannheim and Basel at speeds of 55 to 62 miles per hour over long stretches, sometimes reaching 68.5 miles per hour on favourable parts. With loads of 190 tons up gradients of 1 :61.5, the speed has averaged 34.2 miles per hour, and with 205 tons up gradients of 1 :58.5 the speed has averaged 28 miles per hour.

A similar type of engine built for the State Railways of Württemberg by the Esslingen Engine Works is shown in Fig. 18. This has plate frames, set in towards the back end to allow side-play to the trailing radial axle to the extent of 3 inches in either direction. This motion is not controlled in any way by check springs. The low-pressure cylinders are placed outside the frames and the high-pressure between the frames, all driving on to the middle coupled axle. All four piston valves are driven off the outside return crank-pins, the low-pressure direct and the high-pressure through rocking levers. The firebox has two fire doors. The ash pan is made in three pieces and extends from side to side of the wide firebox, the main frames passing through spaces provided for this purpose enclosed by plates. Owing to the "switchback" nature of the roads over which these engines run, and the consequent frequent variations of power necessarily exerted, the high-pressure cylinder diameter has been made rather larger than would have otherwise been the case, giving a volume ratio of 1 :2.22. The cylinders are 16.53 inches and 24.4

inches by 24.1 inches stroke, drivers 5 feet 10.87 inches diameter, and pressure 213 pounds per square inch, giving maximum tractive force of 9.53 tons.

Starting is effected by opening the by-pass cocks connecting both ends of the high-pressure cylinders and opening the regulator. Steam passes through the cylinders and into the receiver space. When this has attained about 115 pounds pressure, shown on a gauge in the cab, the driver shuts the by-pass cocks and the high-pressure cylinders get full boiler pressure steam in the ordinary way.

On trials, these engines have taken 400 tons up 6.2 miles of 1:100 gradient at 43.5 miles per hour, and 470 tons up 7.5 miles of 1:270 at 56 miles per hour, the indicated horse-power being 1,800 and 1,860, the drawbar pull being 5.3 and 4.13 tons, respectively, and the contract conditions specified speeds of 62 miles per hour on the level with 345 tons behind the tender. The greatest allowable speed is 68.5 miles per hour.

Fig. 19 shows a four-cylinder, divided and balanced compound engine with Schmidt superheater, built by the Société Alsacienne de Construction Mécaniques at their Grafenstaden department, for service on the Imperial Railways of Alsace-Lorraine. These engines are intended for express service with heavy trains on the comparatively easy route from Basel - Strasburg - Weissenberg. The outside high-pressure cylinders, 14.96 inches diameter, drive on to the middle coupled axle, and the inside low-pressure cylinders, 23.62 inches diameter, drive on to the first coupled axle. The boilers have ninety-two Serve tubes, 14 feet 1.3 inches long by 2.56 inches to 2.75 inches diameter, grate area, heating and superheating surfaces of 34.6, 2,055 and 414 square feet, respectively; boiler pressure of 213 pounds per square inch, which, with driving wheels 6 feet 8.32 inches diameter, gives a maximum tractive effort of 8.6 tons.

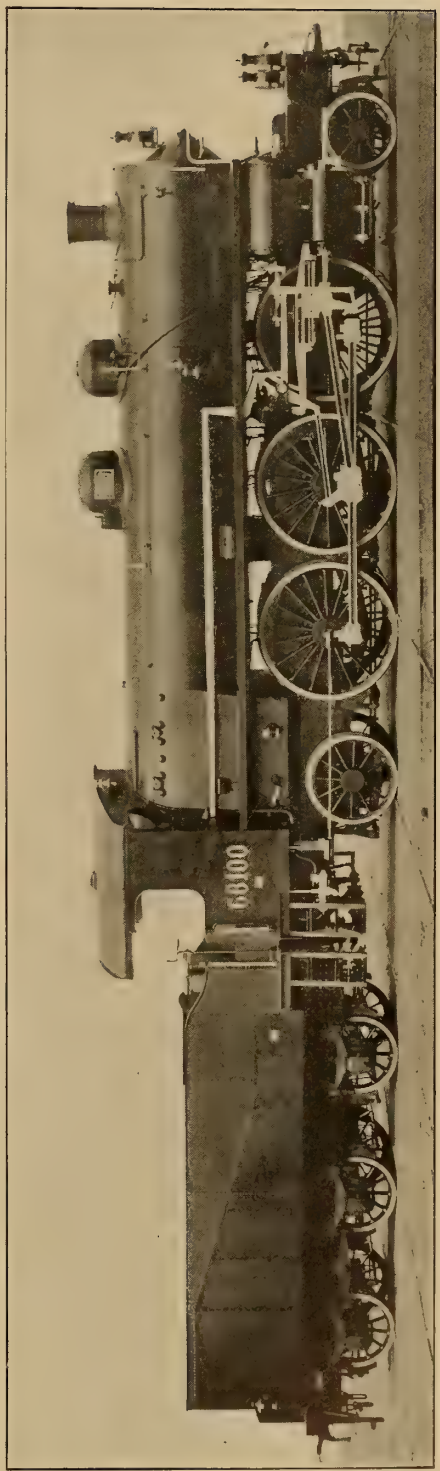


FIG. 21.—FOUR-CYLINDER BALANCED COMPOUND 2-6-2 ENGINE AND TENDER FOR THE ITALIAN STATE RAILWAYS, BUILT BY THE BERLIN ENGINE-BUILDING COMPANY, AND ALSO BY ERNESTO BREDA, MILAN

FIG. 22.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-0 ENGINE AND TENDER, IMPERIAL RAILWAYS OF ALSACE-LORRAINE, BY HENSCHEL & SON, CASSEL

SIX-COUPLED PASSENGER ENGINES, 2-6-2 TYPE

This type of engine, sometimes called the "Prairie" type, is really intermediate between the 4-4-2 or "Atlantic" and the 4-6-2 or "Pacific" type, and is suitable for work for which on the one hand the "Atlantic" type is deficient in adhesive weight or sustained boiler power, or in both of these qualities, and for which on the other hand the "Pacific" type, by reason of its much greater weight and longer wheelbase, may also be unsuitable.

By slightly lengthening the total wheelbase of an "Atlantic" engine, and replacing the second bogie axle by an additional coupled axle, an engine of nearly the same weight is obtained with larger boiler capacity and greatly increased adhesive weight.

In ordinary designs of 2-6-2 engines the rigid coupled wheelbase is increased, as compared to that of the 4-4-2 type, which is often not at all desirable for lines for which the type is otherwise very suitable. In the case of the four-cylinder, balanced compound engine shown in Fig. 21,

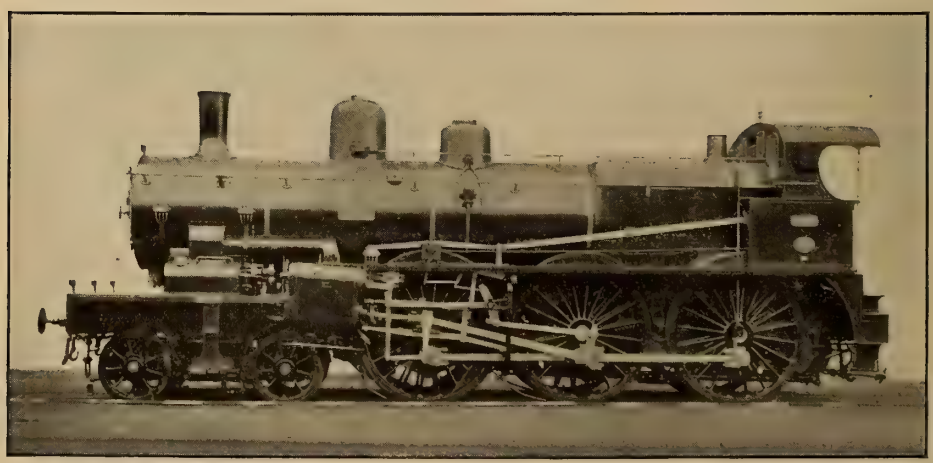


FIG. 23.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND ENGINE WITH SCHMIDT SUPERHEATER, FOR THE WESTERN RAILWAY OF FRANCE, BY HENSCHEL & SON, CASSEL

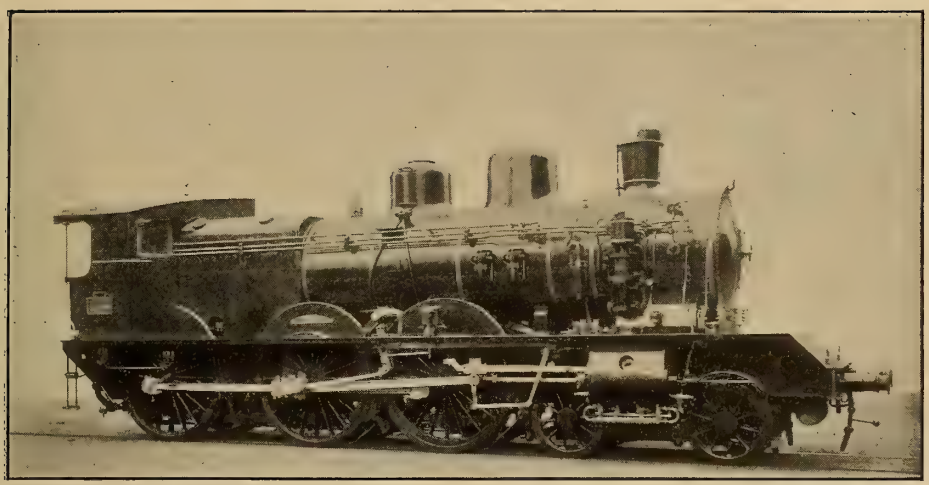


FIG. 24.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-0 ENGINE WITH SCHMIDT SUPERHEATER, FOR THE PARIS, LYONS & MEDITERRANEAN RAILWAY, BY MESSRS. HENSCHEL & SON, CASSEL

built for the Italian State Railways, this difficulty has been avoided by combining the leading wheels and the first pair of coupled wheels in a "Zara" bogie, already described. This engine, therefore, combines the advantages of the 2-6-2 type with the easier running on curves of the "Atlantic" type, and has proved itself very suitable in service. The engine is a four-cylinder, balanced compound, driving on to the middle coupled axle. The loads on the middle, third and trailing axles are equalized by means of levers. "Zara" axle-boxes are fitted to these axles, and the trailer has side-play in addition.

The arrangement of cylinders and valve gear is similar to that of

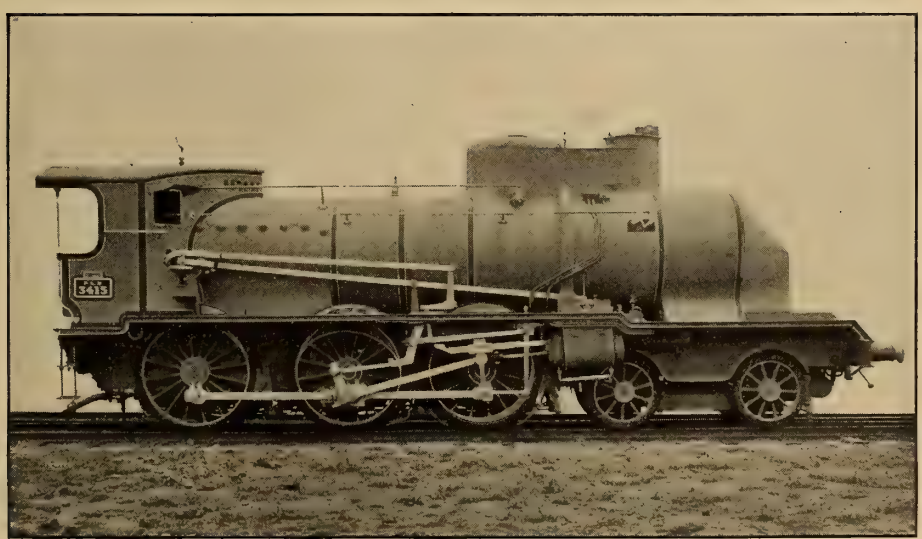


FIG. 25.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND ENGINE FOR THE ALGERIAN SECTION OF THE PARIS, LYONS AND MEDITERRANEAN RAILWAY, BY A. BORSIG, TEGEL, BERLIN

the 0-10-0 four-cylinder, compound Italian State Railways, already described. These engines have been built by the Berlin Engine-Building Company, and also Ernesto Breda, Milan, and from one of the latter engines the photograph was taken.

SIX-WHEELS-COUPLED PASSENGER ENGINES

The engines shown in Figs. 22, 23 and 24 represent designs got out to do heavy express work in flat and also hilly districts, demanding speed up to 62 miles per hour and powers up to 1,500 and 1,600 indicated horsepower, work for which, on the one hand, the adhesion of the "Atlantic" type is insufficient, and on the other the older types of six-wheels-coupled engines were unsuited, owing to their smaller driving wheels.

Fig. 22. The outside high-pressure cylinders drive the middle and the inside low-pressure cylinders drive the first coupled axle. Flat valves are fitted, and separate sets of Walschaert gear, which can be linked up independently. The low-pressure gear is worked off eccentrics placed between the crank webs and the axle-box bearings.

Fig. 23. These engines resemble generally the 2,700 class already running on the Western Railway of France. It is worthy of note, however, that these engines show a saving of coal and water of 20 per cent. over the same class without the superheater. Piston valves with separate sets of independently regulated gear are fitted, arranged similarly to the preceding engine.

FIG. 26.—FOUR-CYLINDER BALANCED SIMPLE 4-6-0 ENGINE WITH SCHMIDT SUPERHEATER, FOR THE BELGIAN STATE RAILWAYS, BY THE SOCIETE ANONYME FRANCO-BELGE, FROM THE DESIGNS OF M. FLAMME

Fig. 24 is a design based on previous engines of the Paris-Lyons and Mediterranean Railway, but the addition of the Schmidt superheater has realized a saving of about 25 per cent. of coal and water. Outside high-pressure and inside low-pressure cylinders drive the second and first coupled axles, respectively. All have piston valves and Walschaert gear, the drive for the low-pressure valves being taken from eccentrics on the middle of the crank-axle and transmitted through a rocking gear to the spindles. The cut-off in the high-pressure cylinders alone can be varied, that of the low-pressure being

FIG. 27.—TWO-CYLINDER SIMPLE 4-6-0 LOCOMOTIVE WITH SCHMIDT SUPERHEATER, BUILT FOR THE SAXON STATE RAILWAYS BY THE SAXON ENGINE WORKS, CHEMNITZ

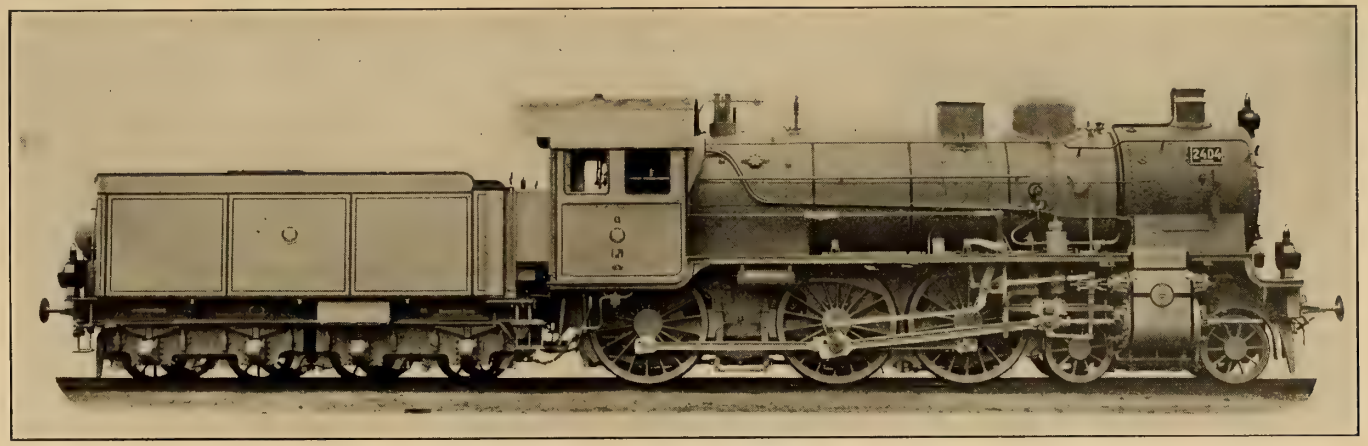


FIG. 28.—TWO-CYLINDER 4-6-0 EXPRESS ENGINE AND TENDER WITH SCHMIDT SUPERHEATER FOR THE PRUSSIAN STATE RAILWAYS, BY THE BERLIN ENGINE-BUILDING COMPANY

FIG. 29.—TWO-CYLINDER SIMPLE 2-6-0 EXPRESS ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, BUILT FOR THE ITALIAN STATE RAILWAYS BY THE BERLIN ENGINE-BUILDING COMPANY

invariable, at 63 per cent., both forward and backward gears. These three engines were built by the firm of Henschel & Son, Cassel.

Fig. 25 shows a four-cylinder, compound express engine for the Paris-Lyons and Mediterranean Railway (Algerian department). The outside high-pressure and inside low-pressure cylinders drive on to the second and first coupled axles, respectively. Flat slide valves are used, the inside having Gooch motion. The reversing gear operates first the high-pressure and then the low-pressure motion, a usual P. L. M. arrangement, giving invariable cut-off to the low-pressure cylinders. The extent to which wind-cutting arrangements have been carried is noticeable. The compounding system is the type of de Glehn as used by this railway, who were responsible for the entire design of the engines, which were built by Herr A. Borsig. Tegel, Berlin, the engine photographed being the seven thousandth turned out from his works.

The engine shown in Fig. 26 is interesting from more than one point of view. In common with several other classes built for the Belgian State Railways, the general outlines of the engine and neatness of design support the thought that a strain of Caledonian "Dunalastair" class blood is in her veins, transmitted, no doubt, from the Scottish-designed engines put to work in Belgium some years ago. Also, it is one of the few designs of simple-expansion, four-cylinder, superheated steam locomotives, and is practically a development of the same class built in 1905 and shown at the Milan Exhibition in 1906. These engines had four cylinders, 17.13 inches by 24.02 inches, while those of the type now described are 17.52 inches by 25.2 inches, the other dimensions and heating surfaces being practically the same. The design is due to Monsieur Flamme, locomotive superintendent of the Belgian State Railways, and the engines were built to take heavy trains at high speeds along the level and up moderate gradients. Forty of these engines are actually, at the date of writing, in service, and, according to M. Flamme's report, are admirably fulfilling the requirements of the traffic, and are remarkable for their smooth running. All four cylinders are placed in line abreast across the engine over the bogie pivot, and drive on to the first coupled

FIG. 30.—TWO-CYLINDER SIMPLE 2-6-0 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, FOR THE PRUSSIAN STATE RAILWAYS, BY HENSCHEL & SON, CASSEL

axle, the crank axle being of the "Z" type so much in vogue on the continent of Europe. Corresponding pairs of cylinders on each side of the engine drive cranks at 180 degrees to each other, the cranks of the crank axle being set at 90 degrees, the arrangement being a 'balanced" system. The four piston valves are driven off two return crank-pins, those of the outside cylinders directly, those of the inside cylinders through rocking levers working in a horizontal plane. The inside valve spindles are coupled to this lever by a single link, and the "swing" of the outer end is allowed for by connecting it to the middle pin of a double link, the two end pins of which are connected to the lap-and-lead lever and valve spindle, respectively. The whole arrangement, therefore, is pin connected and simple, avoiding the complications of slotted levers and die-blocks and pins sometimes used in such transmissions. As usual in superheated steam engines, the valves have inside admission and outside exhaust, and the cylinders and connections show that great care has been exercised to ensure an easy run for the exhaust steam. The ample di-

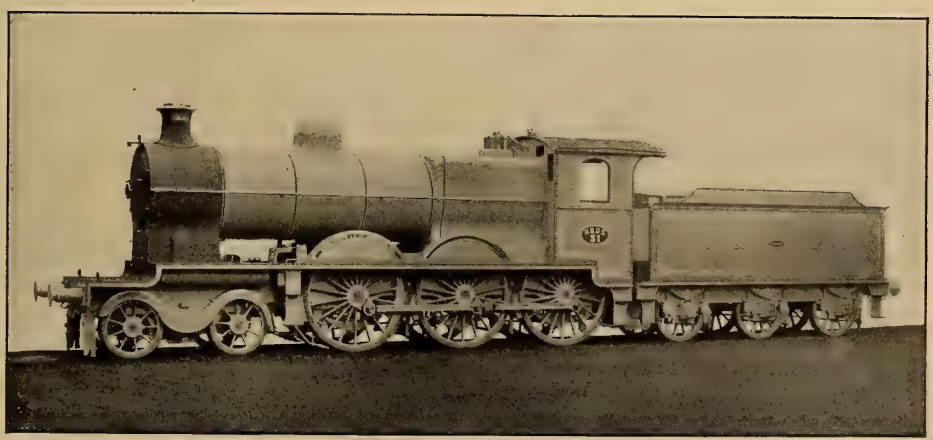


FIG. 31.—TWO-CYLINDER 4-6-0 ENGINE AND TENDER FOR THE NORTH BRABANT RAILWAY, BY MESSRS. BEYER, PEACOCK & CO., LTD., MANCHESTER

mensions of fire-grate and heating surfaces, combined with the cylinder arrangement, indicate an engine of great power and flexibility, capable of rapid acceleration at starting, and of giving out temporarily a power much in excess of its average, combined with easy running at high speeds—all very desirable qualities for the work these engines have to do.

Fig. 27.—A two-cylinder, simple, Schmidt superheater engine, State Railways of Saxony. This engine was built by the Saxon Engine Works, Chemnitz, to take heavy trains on hilly lines, involving gradients of 1:100, with speeds up to 62 miles per hour on the level. These conditions involve the use of large-capacity cylinders and a medium diameter of coupled wheels combined with ample reserve of steaming capacity. The dimensions to be found in the table show that these conditions have been satisfied, and a comparison with those of the next engine to be described, intended for similar work on other lines, is interesting as showing how nearly independent designs approximate to each other. See also Fig. 36 description.

Fig. 28 shows a type of express passenger engine which is doing excellent service on the Prussian State Railways. The general design is due to Herr Privy Councillor Garbe, of the central administration of the Prussian State Railways, and the detailed designing and construction were undertaken by the Berlin Engine-Building Company, the engines conforming generally to the latest Prussian State practice for superheated steam locomotives. Built especially for heavy and rapid haulage on difficult lines, these engines are quite coming up to the expectations of their designers and builders, and are well spoken of by their drivers as being powerful and elastic machines, capable of tackling big loads under adverse conditions of rails and weather. Though built especially for express passenger service, the design is one of general utility. On trial, these engines have taken 56 axles and 464 tons behind the tender over 123 miles of heavily graded road, with five booked stops, at an average running speed of 37.3 miles per hour, attaining 62 miles per hour on the level. These results could have been improved upon but for the fact that the trial train had to be worked in between ordinary trains running to time-table. A developed power of 1,980 horse-power has been observed on trial with about 400 tons behind the tender. The earlier engines of this class had "wind-cutter" cab-fronts, but the later ones have flat-fronted cabs, as shown in the photograph.

Fig. 29 shows an engine built for the Italian State Railways by the Berlin Engine-Building Company which is interesting from the fact that it was designed to run against an already existing type, a compound "wet steam" engine. The new design altered nothing excepting those parts necessarily changed through the adoption of superheated steam, and affected mainly the boiler and cylinders. Wheels, wheelbase and overall dimensions remain the same, only 0.15 ton being added to total loaded weight. The engines were intended to take express trains of medium weight at fast speeds over lines with moderately level profile. The rigid wheelbase has been reduced to 7 feet 4.6 inches by combining the leading axle and the first coupled axle in a "Zara" bogie. Zara's patent axle-boxes are fitted to the second and third coupled axles. "Trick" ported piston valves are used, of the "Fester" type, fitted with a tongue-piece at the joint of the packing rings. The cylinders, placed between the frames, are somewhat steeply inclined (about 1:7:35), to clear the front coupled axle, and drive on to the middle axle of the "Z" type. The lap-and-lead levers are driven by an extra return crank-pin.

In actual service these engines have shown a marked superiority

over the compound engines of similar dimensions in coal and water consumption, especially with heavy trains. These engines have been found capable of a maintained effort of 1,000 to 1,050 indicated horse-power, or 0.86 to 0.9 indicated horse-power per square foot of heating surface.

Fig. 30 shows one of the latest types of heavy passenger engines on the Prussian State Railways. They

FIGG. 32.—FOUR-CYLINDER DIVIDED AND BALANCED COMPOUND 4-6-4 TANK ENGINE FOR THE PARIS, LYONS AND MEDITERRANEAN RAILWAY, BY THE HANNOVER ENGINE-BUILDING COMPANY

are capable of taking 424 tons behind the tender at 43.5 miles per hour. The leading axle and the first coupled axle are combined in a "Krauss" bogie, reducing the fixed coupled wheelbase to 6 feet 6.75 inches. The design, generally, follows the Prussian State standards for superheated steam engines. The engine photographed was built by Messrs. Henschel & Son, Cassel.

Anyone who is sufficiently interested to wish to observe the great fixed gulf between typically British and typically Prussian State-designed locomotives, cannot do better than travel by one of the heavy mail trains through Holland as far as Boxtel, continuing thence via the North Brabant Railway over the German portion to Oberhausen. At Boxtel the train will in all probability be taken over from the Dutch State Railway engine by one of the engines shown in Fig. 31, which were designed by Messrs. Beyer, Peacock & Co., Ltd., Manchester, for heavy passenger service on the North Brabant Railway. At Oberhausen this engine will be relieved by a Prussian State engine, and the visitor will have plenty of time to make comparisons of the English-designed engines and her German cousins, to be seen in great variety about Oberhausen—comparisons of points that are suggestive of much that differentiates between the ideas of British and German draughtsmen. The North Brabant engines have cylinders 19 inches by 26 inches stroke, placed between the frames, fitted with flat balanced valves on top, with Walschaert gear driven off eccentrics on the crank axle. The first coupled axle is the driver, and the coupled wheels are 6 feet 6 inches diameter, giving, with 200 pounds per square inch boiler pressure a maximum tractive force of 8.07 tons. The line has easy curves and gradients, and

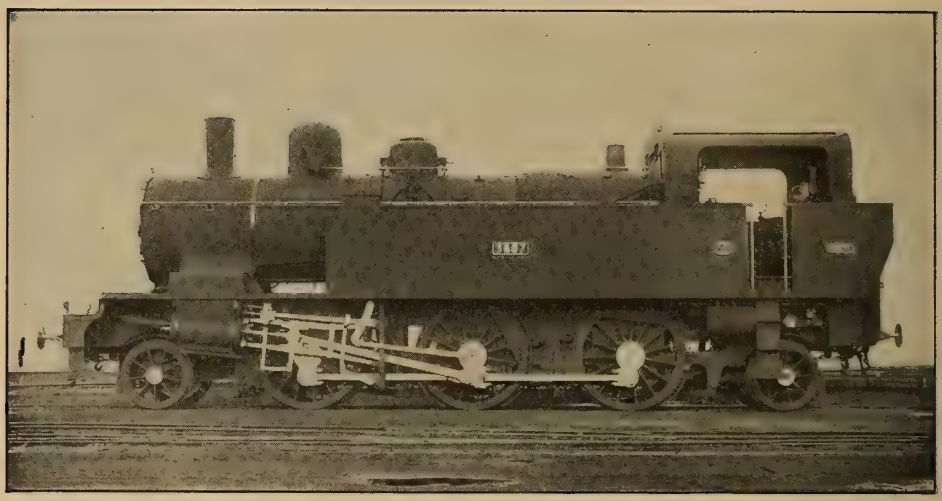


FIG. 33.—FOUR-CYLINDER BALANCED 2-6-2 TANK ENGINE FOR SUBURBAN SERVICE ON THE WESTERN RAILWAY OF FRANCE, BUILT BY THE SOCIETE ALSACIENNE DE CONSTRUCTIONS MECANIQUES, BELFORT

the engines were designed to haul 400 tons at 60 miles per hour; and on trials they have very considerably exceeded this figure, and are doing excellent work in actual service.

SIX-WHEEL COUPLED TANK ENGINES

A very powerful engine of this type, arranged as a 4-6-4, four-cylinder, divided and balanced compound, is shown in Fig. 32, taken from an engine built for the Paris-Lyons and Mediterranean Railway by the Hannover Engine-Building Company. The outside high-pressure cylinders drive the second and the inside low-pressure cylinders drive the first coupled axle. The compounding is the P. L. M. arrangement of the De Glehn system, and the engine generally conforms to the practice of that railway. With its large grate area, heating surfaces and tractive force, this engine is capable of dealing with heavy trains, and can be used for a large variety of traffic.

Fig. 33 shows a six-wheels-coupled tank engine with 2-6-2 wheel arrangement, built by the Société Alsacienne de Constructions Mécaniques in 1908 at their Belfort works, for the Western of France Railway. These engines are noteworthy as being, up to the present, the only 2-6-2 type tank engines built as four-cylinder compounds, and they are used for suburban service. In order to ensure a clear lookout for the driver, all the gear for actually driving the engine is duplicated, so that he can face the direction of running when the engine is traveling coal-bunker first. The leading and trailing axles are carried in Bissel trucks, and the spring gear of leading and first coupled axles is connected up by means of compensating levers, as is that of the second and third coupled axles and the trailing axle. Sixty-nine per cent. of the total loaded weight is carried on the coupled axles, of which the second is the driving axle, giving an adhesive coefficient of 6.25; and even on the supposition of tanks and bunker being empty, this is only reduced to about 5.4, so it will be seen that this engine can take full advantage of its power at starting—an important factor when the service the engine has to do is considered.

Fig. 34 shows a class of engine recently built by Herr A. Borsig, Berlin, for the Prussian State Railways, for service on express trains between Frankfurt-am-Main and Wiesbaden. This is a run of only about 26 miles; but the trains are heavy, necessitating powerful engines. These have been built with the Schmidt super-

FIG. 34.—TWO-CYLINDER SIMPLE 2-6-0 EXPRESS TANK ENGINE WITH SCHMIDT SUPERHEATER, FOR THE PRUSSIAN STATE RAILWAYS, BY A. BORSIG, TEGEL, BERLIN

heater, and the details of the engines conform generally to recent Prussian State practice.

An interesting design of tank engine is shown in Fig. 35, in that the water tank, holding 6.4 tons, is built up between the main frames. It runs from the smoke-box front to within a very short distance of the firebox front, and extends the full depth of the frames, the driving axle working in a pocket. These engines were built for taking heavy stopping trains on the North Milan Railway, where the gradients are, in places, severe, by Messrs. Henschel & Son, Cassel. To ensure steady running at high speeds, the front end of the engine is carried on a bogie, whose under pivot bearing swings on links. For running on long downhill stretches, by-pass cocks with large passages have

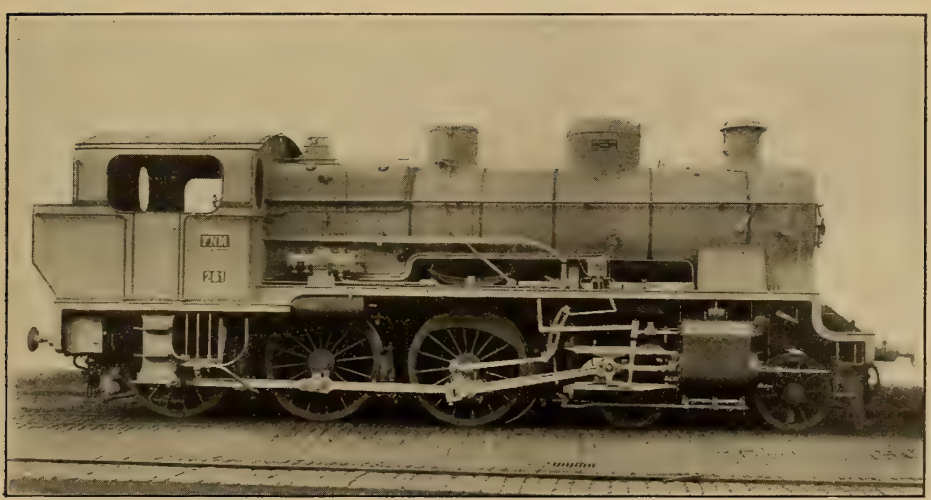


FIG. 35.—TWO-CYLINDER SIMPLE 4-6-0 PASSENGER TANK ENGINE FOR THE NORTH MILAN RAILWAY, BY HENSCHEL & SON, CASSEL

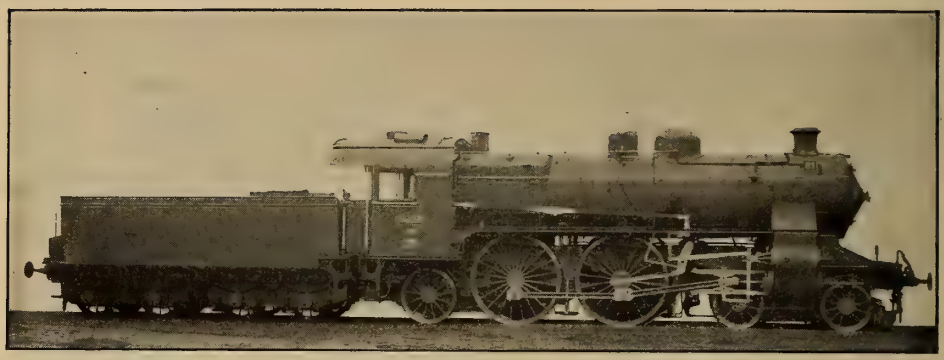


FIG. 36.—TWO-CYLINDER SIMPLE 4-4-2 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, FOR THE STATE RAILWAYS OF SAXONY, BY THE SAXON ENGINE WORKS, CHEMNITZ

been fitted to the cylinders. Schmidt's superheater is fitted, of the usual smoke-tube type. The maximum tractive force is 8.2 tons, and the adhesive coefficient varies between 4.92 maximum and (about) 4.5 minimum when tanks and bunker are empty.

FOUR-WHEEL COUPLED "ATLANTIC" TYPE ENGINES

A recent example of this type is shown in Fig. 36, built for the Saxon State Railways by the Saxon Engine Works, Chemnitz. This engine was required to take heavy express trains on fairly level lines, the maximum allowable speed being 74.5 miles per hour. With this end in view, the cylinders have been made 20.08 inches by 24.8 inches stroke and the driving wheels practically 6 feet 6 inches diameter. The boiler duplicates with that of the 4-6-0 class, Saxon State Railways, by the same builders (see Fig. 27); also, the same general cylinder arrangements are used, with, however, a difference in diameter of 3.94 inches, those of the 4-6-0 class being 24.02 inches by 24.8 inches stroke. The piston valves are of the "Fester" type, having spring rings and Trick ports. The trailing axle under the firebox has fixed bearings, giving a rigid wheelbase of 13 feet 7.4 inches. The leading bogie has its own brake cylinder and gear, and has 2.9 inches total side-play, the load being carried on suspension links. The coupled and trailing axle springs are compensated; 31.5 tons are carried by the coupled axles, giving a coefficient of adhesion of 4.3, calculated on a maximum tractive force of 7.33 tons.

The engine shown in Fig. 37 is more than usually interesting, as representing the latest word on four-cylinder, von Borries system, compound engines from the Prussian State Railways, on which this system, both in its two-cylinder and, later, its four-cylinder arrangement, has been successively developed from its first application in 1880 until the present day. This type, known as the S.9 class, is really an enlarged edition of the S.7 class, with alterations in details, and both classes have been built in large numbers by the Hannover Engine-Building Company.

These engines are intended for very heavy and fast trains on lines that are fairly level, involving long runs between stopping places. For instance, the trains on the Berlin-Hannover route sometimes amount to 60 axles = 510 tons behind the tender; and the writer has more than once traveled behind these engines in rough weather with 52 axles = about 445 tons behind the tender, on trains making non-stop runs of 158 miles at a booked average speed of 50 miles per hour, the engines easily managing this load and keeping good time.

It will be seen, therefore, that very powerful engines with ample steaming capacity are required for the work, and an examination of the dimensions of these engines shows that these requirements have been satisfied. The cylinders are 14.96 inches and 22.83 inches by 23.62 inches stroke, volume ratio 1 :2.33, and driving wheels are 6 feet 5.95 inches diameter, giving, with a boiler pressure of 198 pounds per square inch, a maximum tractive force of 7.22 tons; an adhesive weight of 32.5 tons out of a total of 73.5 tons—i. e., 44.3 per cent. gives an adhesive coefficient of 4.63. The wide firebox gives a grate area of 43.06 square feet, and the heating surface of box and tubes is 2,542 square feet.

The high-pressure cylinders are placed outside the frames and the low-pressure cylinders between the frames, all driving to the first coupled axle, the arrangement adopted being that of a balanced compound. One high-pressure and one low-pressure cylinder, with their two piston valve chests and half-saddle, are joined in the middle line of the engine to a corresponding casting on the other side of the engine; the main frames are in three parts, plates of 1.1 inches carrying the trailing radial axle and the firebox being spliced to plates of 1.18 inches, taking the two coupled axles, and bars are bolted to these and run forward to the front buffer-beam, passing between the high-pressure and low-pressure cylinder barrels, being fastened to the cylinder casting by means of five bolts on each side. The saddle is also bolted to the smoke-box floor, 1 inch thick, by means of twenty-six 1⅛-inch bolts. The cylinder connection to the bar frames, as seen during erection, seems at first sight to be insufficient, but as this construction has been applied successfully to a large number of engines, it must be taken as being a striking testimony of the smooth running of the four-cylinder, balanced compound engine. The load on the bogie is transmitted through the cylinder casting, and the side-play allowed is 1.97 inches, the radial axle having 1.57 inches side-play in either direction. The piston valves of the high-pressure cylinder are direct driven by the return crank-pins on the outside of the engine, the motion being transmitted to the low-pressure valve spindles by rocking

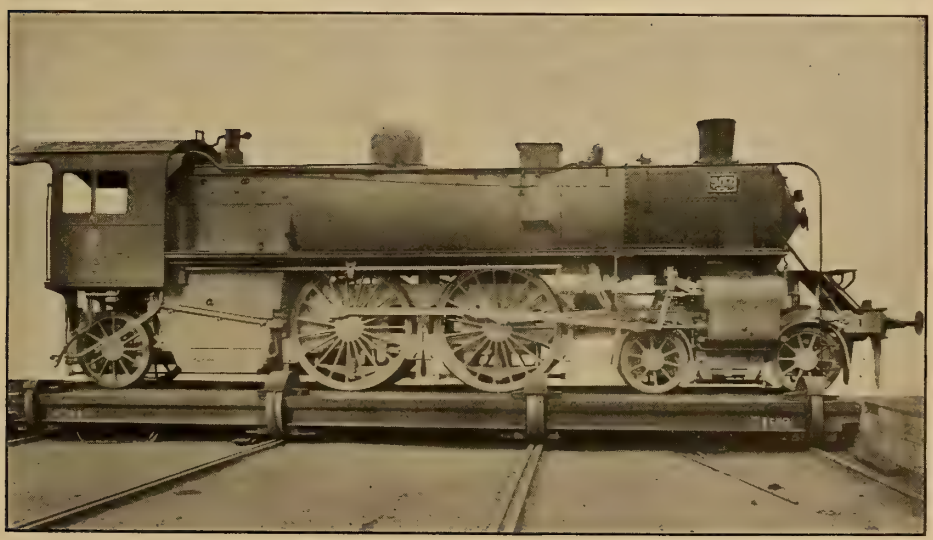


FIG. 37.—FOUR-CYLINDER BALANCED COMPOUND 4-4-2 ENGINE FOR THE PRUSSIAN STATE RAILWAYS, BY THE HANNOVER ENGINE-BUILDING COMPANY

shafts; but each valve spindle has its own lap-and-lead lever driven off the crosshead. Double steam ports are used for all cylinders, the high-pressure having inside and the low-pressure having outside admission. The regulator is of the Schmidt and Wagner circular balanced type, which, when slightly opened, admits steam both to the high-pressure cylinders direct, and also through a special pipe, to the receiver and to non-return valves in fittings placed in the middle of the length of the high-pressure cylinders. The function of these latter is to counteract the back pressure on a high-pressure piston in case the high-pressure piston valve is in such a position that steam is cut off from the other side of the piston, which takes place at about 70 per cent. of the stroke. Further opening of the regulator closes the passage.

The boiler has one coned course of plating joining the piston casing to the front barrel course, the bottom of this course, however, being horizontal. Two fire doors are provided; foundation-ring is 3.54 inches wide at the sides, water space increasing to 5.3 inches at the top row of side stays. To obtain flexibility in the copper stays, their diameter in the shank is made 0.866 inch, and they are spaced 3.7 inches apart. The feed-water is introduced through valves right in the front of the barrel at the top and taken through an internal pipe to a broad tray above the top row of tubes. The double bogie tender carries 30.7 tons of water and 9.05 tons of coal, the loaded weight being 62 tons, making, together with the engine weight of 73.5 tons, a total of 135.5 tons. Owing to the expense of fitting water pick-up apparatus to the tenders, and also the difficulty of keeping the troughs in working order during the severe winters, the Prussian State Railways have never adopted them; but the hauling of so much non-paying weight as is represented by these huge tenders must be in itself a very appreciable percentage of the total haulage costs of the trains.

These engines have repeatedly taken heavy and fast trains between Dortmund and Berlin, and, according to the report of the Hannover administration, without the least difficulty, so that, if necessary, it could be done regularly, the crew being changed at Hannover. As this distance is 290 miles, it must be acknowledged to be a very fine performance, if it does not, indeed, constitute a record.

FOUR-WHEEL COUPLED 4-4-0 TYPE ENGINES

The engine shown in Fig 38, built for the State Railways of Oldenburg by the Hannover Engine-Building Company, though not remarkable for its power or weight, as compared with the engines which have been described before, is, nevertheless, deserving of description in some detail on account of several interesting features of the design. The steam distribution is by means of "Lentz" valves, a form of double-seated valve, actuated by means of a reciprocating rod having hardened, cam-shaped surfaces which engage with hardened steel rollers mounted in the valve spindles. This cam-rod is worked off an ordinary Walschaert motion. This type of valve and gear has been successfully fitted to stationary engines for some years past, but it is only comparatively recently that it has been applied to locomotive work. Up to date, however, some fifty locomotives have been fitted with these valves, including goods and express engines, simple, compound, "wet-steam" and superheated-steam engines. A Prussian State Railway engine, S.7 class, 4-cylinder compound, 4-4-2 heavy express type, exhibited at Milan in 1906, fitted with these valves for the high-pressure cylinders, has since then run 118,000 miles on express service without any trouble with the Lentz valves; and if such results continue to be forthcoming one will be forced to the conclusion that a formidable rival to the slide-

valve has arrived on the scene. Drop-valves certainly possess several advantages over slide-valves, especially for special purposes. Owing to their quick opening and closing, a better indicator diagram can be obtained, with an absence of wire-drawing; whilst for use with highly superheated steam they have the advantage of being without rubbing surfaces under pressure, the lubrication of which, in the case of slide-

FIG. 38.—TWO-CYLINDER COMPOUND 4-4-0 ENGINE, WITH LENTZ VALVES, FOR THE OLDENBURG STATE RAILWAYS, BY THE HANNOVER ENGINE-BUILDING COMPANY

valves, is a matter that requires great care. Incidentally, these valves act as safety valves of large area to the cylinders, being held down on their seats only by springs. The valve gear, as designed by the Hannover Company, certainly had the advantage of great simplicity and accessibility, the spindles being without ordinary packing, relying on the accurate fitting in the first place and also on the labyrinth or groove packing. The actual working parts run in oil, and are enclosed in a dust-proof casing.

The principal objection urged in the past against drop-valve gear being fitted to high-speed engines was that it is, under these conditions, noisy, shows excessive wear and tear, and is liable to breakage. Improvements, both in materials available and appliances for their manufacture, not to speak of design, perhaps make easy to-day what was difficult or impossible a few years ago. The locomotive engineer is instinctively conservative, and advisedly so, and both those who have been bold enough to design, and also to put into service, a new form of valve gear, deserve the thanks of their fellows, whatever the ultimate result. Actual results achieved in the present instance, however, seem to indicate that their confidence has not been misplaced.

In the present case, as stated, the ordinary Walschaert motion has been fitted, and both high-pressure and low-pressure cylinders have Lentz valves, those of the latter being 7.48 inches diameter. The starting arrangements of this engine are interesting, and are the invention of Herr Ranafier, one of the directors of the State Railways, who claims to have overcome one of the objections to the use of the two-cylinder compound—

i. e., its small starting effort in certain positions of the pistons. The operation is as follows: An extension of the high-pressure valve spindle actuates, by means of cam-surfaces and a roller, a non-return valve ordinarily held up to its seat by a spring. This non-return valve communicates with a pipe opening into the high-pressure cylinder midway along its bore, and the cam-surfaces referred to are so spaced as to allow this valve freedom to fall away from its seat whenever the high-pressure steam admission valves have cut off steam at either end of the cylinder, and to remain free until the end of the stroke, when it is held up to its seat again.

At starting, the driver opens the regulator, which admits steam to the main steam pipe and also to a small pipe leading to a cylindrical chamber containing a piston valve controlling two ports. He then pulls a handle attached to the spindle of the valve, and the piston uncovers at first a port leading to the non-return valve referred to. In any high-pressure piston position, therefore, the high-pressure cylinder receives steam, either direct through its admission valve or through this port and past the non-return valve. If the engine does not start, a further movement of the handle causes the piston valve to uncover also the second port, which communicates with the receiver, whose safety valves blow at about 85 pounds per square inch. The force available for starting is then 85 pounds per square inch on the low-pressure piston + (170 — 85) = 85 pounds per square inch on high-pressure piston. The steam pressure in the starting piston-valve chamber tends to move the valve into simple working position, and the non-return valve, on account of a cylindrical guide, only admits steam past itself when it has moved some 4 to 5 millimeters away from its seat. This arrangement allows the non-return valve and roller to be lifted entirely clear of the cam-rod when working compound. The Ranafier "steam dryer" is fitted between the high-pressure and low-pressure cylinders, and consists of two sets of steel tubes, 1.8 inches outside diameter, bent to an inverted U-shape, the ends of which are expanded into two chambers, one on each side of the smoke-box, which communicate with high-pressure and low-pressure cylinders, respectively. The tubes are forty-six in number, arranged in two sets of four rows each, one in front of and one behind the blast-pipe. The tubes are shaped to give clear access to all boiler tubes for clearing purposes, and, incidentally, make a good spark-breaker. The steam in its passage from high-pressure to low-pressure through these tubes is dried, and also has its temperature raised somewhat.

With loads of thirty-four axles = 342 tons, on lines having many gradients of 1:300 and 1:500, speeds of 42.25 miles per hour are attained, and trains of 425 tons, of average speeds of 28 to 34 miles per hour, are taken between Wilhelmshaven and Oldenburg, involving gradients of 1:300 to 1:200. Lighter trains, at speeds up to 56 miles per hour, are also handled. Trials have proved these engines with Ranafier starting gear to be able on the level to start trains of 58 axles = 510 tons in any position of the cranks.

Very interesting trials between three of these Lentz-valve engines and five exactly similar engines fitted with flat slide-valves, extending over three months, until July, 1909, on exactly the same classes of service, have given the following results:

Five slide-valve engines ran 44,217 miles total, using 68.6 pounds coal per 100 axle-miles.

Three Lentz-valve engines ran 20,719 miles total, using 62.7 pounds coal per 100 axle-miles, or a saving of 8.6 per cent.

And, further, contrary to the experience with slide-valves, the Lentz valves seemed to become even more

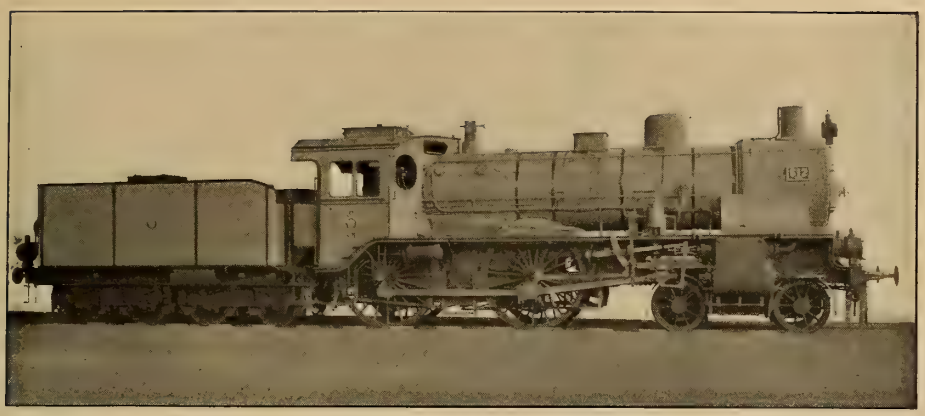


FIG. 39.—SIMPLE 4-4-0 ENGINE AND TENDER WITH SCHMIDT SUPERHEATER, FOR THE PRUSSIAN STATE RAILWAYS, BY HENSCHEL & SON, CASSEL

steam-tight on their seats with service.

Results such as those already obtained with these valves indicate that reports of their behaviour during an extended experience will be of great interest to locomotive engineers.

Last, but by no means least in either interest or importance, comes the engine shown in Fig. 39—a two-cylinder, simple-expansion, superheated steam engine for express service on the Prussian State Railways. These engines have been built in considerable numbers, both by the Breslau Engine-Building Works and Messrs. Henschel & Son, Cassel, the photograph being taken from one of those built by the latter firm. These engines are amongst the heaviest, if not, in fact, the very heaviest, 4-4-0 engines running on the continental lines of Europe. The cylinders are 21.65 inches by 24.8 inches stroke, coupled wheels 6 feet 10.68 inches diameter, and boiler pressure 170 pounds per square inch, giving a maximum tractive force of 8.03 tons. The total loaded weight of engine is 58.75 tons, of which 33.4 tons, or 56.8 per cent., is carried on the drivers.

The design is due to Privy Councillor Garbe, of the central administration of the Prussian State Railways, whose views on what constitutes the best type of engine for fast and heavy express work under conditions such as at present hold good on those lines are well known to most locomotive engineers. It is sufficient, therefore, to say that the engine here shown represents his ideal, which, briefly stated, is a two-cylinder, simple-expansion, highly superheated steam engine of the 4-4-0 type, with moderate boiler pressure; and if such an engine can be built to satisfy all demands of the traffic department there are few who will disagree with him. He is of the opinion that the two-cylinder engine, as here arranged, can run as smoothly as any arrangement of four-cylinder, "balanced" engine, either simple or compound, and that to build engines of this latter type is an unnecessary outlay of money.

As is the case on many Continental railways, the permissible axle loads are so restricted that, in order to take heavy trains at fast speeds with a four-wheels-coupled engine, it is necessary to utilize the adhesion of the engine to the utmost under many working conditions, and, therefore, to eliminate as far as possible any factors that may exercise a disturbing effect on the adhesion, the principal ones being those due to the parts of the balance weights placed in the wheels to balance a propor-

tion of the reciprocating weights in ordinary designs of two-cylinder engines. These, however, introduce unbalanced vertical components, varying in amount, tending to increase the wheel load on the rail during one-half of the revolution of the wheel and to decrease it during the other, and so causing periodic fluctuations in the available adhesive weight. Viewed, also, in relation to the rails, these parts of the balance weights have a cycloidal path, giving rise to the hammer-blow on the rails so much detested by the permanent-way engineer, more especially when his roadbed is not adequate to meet modern requirements.

Comparing this 4-4-0 engine with the four-cylinder, balanced-compound 4-4-2 engine shown in Fig. 37, having almost the same adhesive weight—i. e., 33.4 tons for the former and 32.5 for the latter—it will be seen that in the case of the latter engine, the reciprocating weights of which practically balance each other (leaving couples out of consideration), the nature of its design enables it to utilize its adhesion to the best advantage without special provision.

In the case of the 4-4-0 engine now under notice, the bold step has been taken of dispensing altogether with any attempt to balance part of the reciprocating weights of the engine, thus getting entirely rid of this influence disturbing the adhesive weight. As was to be expected, this has considerably affected the steady running of the engine in other directions. Taking the ordinary "wet-steam" 4-4-0 engine and comparing it with the 4-4-0 engine shown in Fig. 39, it has been found by experiment, when running with a slack coupling between engine tender, that the periodic relative displacement between them, due to these unbalanced forces, is 3.8 millimeters and 5.7 millimeters, respectively—6.145 inches and .224 inches—or an increase of 50 per cent. for the latter engine. In order to reduce as much as possible the effect of these unbalanced forces, the draw-gear spring between engine and tender has been strengthened and the initial load on it increased from 1.97 to 4.92 tons, or 150 per cent., and in this way the inertia of the tender has been called into requisition to assist that of the engine in resisting them. The fact must not be lost sight of, however, that before reaching the rear end of the engine these forces have to be transmitted through the moving parts of the fixed framework, and this has necessitated a stiffening up of cylinder connections and framework generally to resist them.

The whole idea is certainly original, and as such deserves credit. One cannot help thinking, however, that once more "necessity" has been "the mother of invention," and that, in spite of the contention of commercial Privy Councillor Dr. Haarmann (Association of German Iron-works Officials, Düsseldorf, 8/12/07, see "Railway Gazette," 3/4/08) that the permanent way of the Prussian State Railways meets all modern requirements; if a considerably higher axle load had been permissible, a more normal arrangement might, perhaps, have been adopted. The lot of the British locomotive superintendent, though a hard one, is, by comparison, happy—witness the latest 4-4-0 express passenger engine on the North Eastern Railway, with loads of about 21½ tons on the coupled axles, the reversion on this latter railway, also, from various types of 4-4-2 engines to the simpler 4-4-0 engine being interesting.

The comparatively small grate area, 24.6 square feet, implies a high rate of combustion when the engine is exerting its full power. In other respects the engine conforms to Prussian State practice.

There is a belief in many quarters that, owing to considerations of brakes and length of trains, the loads now being taken by the engines shown in Figs. 37 and 39 represent the maximum that is ever likely to be

asked for, and that, therefore, more powerful engines will not be required. This presupposes that conditions now prevailing are likely to remain unchanged; but in view of developments in other countries, one hesitates to endorse this view, but rather to suppose that, like the astounded workhouse master in "Oliver Twist," the locomotive superintendents in this case also will again be asked for "more." If this happens, either greater rail loads must be permitted or greater adhesion obtained by the use of a third coupled axle. In the meantime, these 4-4-0 engines are undoubtedly doing excellent work, and are capable of pulling a load of 356 tons behind the tender at speeds of 62.2 miles per hour, developing an average of 1,100 horse-power.

CONCLUSION

No one familiar with locomotive building, both in British and in Continental works, can fail to be impressed with much that distinguishes the designs turned out from the former, as compared with the latter. On the one hand, much is sacrificed for the sake of simplicity and reduction of the number of parts; on the other, one would think that complication had actually been aimed at. More especially is this the case when Continental manufacturers are working to the designs of some of the railway companies; when allowed a free hand, as often happens in designing for export to distant countries, it is interesting to note how closely the designs not infrequently approximate to British ideas of simplicity. Had not the limits of this article forbidden, it would have been interesting to have included some of the latter for the sake of comparison. These remarks apply to the general features of design, but the same may be said of the structural details. In the case of more than one of the engines described, and more especially is this true of some of the engines of French design, the complexity of many of the structural details to be seen in the works during building is amazing, and must make their machining and fitting unnecessarily expensive. In simplicity and straightforward designing of details, in the opinion of the writer, the British draughtsman is unexcelled, and this statement is confirmed by what he has heard from those who have had much experience with both British and Continental-designed engines in actual work.

More than once it has been remarked to the writer by competent authorities on the Continent that the cheapness of coal in England has stood in the way of the general development of the steam engine, and with important reservations there may be a good deal of truth in the statement. This remark should be borne in mind when passing judgment on some of the designs included in this article. What might, if fitted to a British locomotive, save 5 per cent. of coal, and still be a bad investment of capital, if fitted to an engine burning coal costing 25 shillings a ton, might show a handsome return on the outlay.

The use of open-hearth basic steel almost exclusively throughout the Continental locomotive is rank heresy in the eyes of British locomotive engineers, but inquiry fails to reveal any case of one of them canceling his arrangements for a Continental trip on account of the extra risk involved thereby; and the English Lloyds accept this material for ships and boilers built under their survey, in which their underwriters have heavy financial interest.

The extent to which two and four-cylinder compounds are used is also in marked contrast to British practice, and the rapidity with which the superheated steam locomotive has been adopted is little short of marvelous, considering the comparatively short time that has elapsed since the first practicable system was adapted to locomotive work. The Prussian State Railways, with the whole-

hearted support of Herr Geheimer Baurat Garbe, have nearly 2,000 either built or on order, and the system has been applied to engines for use in most out-of-the-way places. True, it has had influential backers on many of the great railway systems of the Continent, but unquestionably it stands where it does on its own merits.

An examination of the classification of the forty-two engines included in this description is interesting, and is given below:

Viewed in the light of these figures, and supposing them to be representative, the plain, two-cylinder, single-expansion, "saturated-steam" locomotives make but a very poor show, and seem in danger of becoming extinct, as far as the mainland of Europe is concerned. The use on recently designed engines of the Walschaert valve gear is almost universal.

Each system of steam using has its strong advocates. The saturated-steam, simple-expansion man argues the great simplicity of his engine. The four-cylinder, compound, saturated-steam man, on the other hand, points with pride to his latest production as being the ideal creation, to which replies the highly-superheated steam man that the two-cylinder, simple-expansion, moderate-boiler-pressure engine of that ilk is the most perfect imaginable, both on the score of first cost and also economy in working. And yet, again, the newly arrived four-cylinder compound, highly-superheated-steam-combined-with-high-boiler-pressure man offers to produce figures undreamt of by either attained by adopting his system.

The extinction of the steam locomotive, and its relegation to the scrap-heap and to museums for the preservation of samples of obsolete products during the lifetime of those present, has been proclaimed on many occasions by prophets of various calibres into the ears of generations of listeners, most of whom are long since dead. Up to date, however, scrapping on a large scale has been applied to the steam locomotive mainly by newly appointed superintendents of motive power to the pet engines of their predecessors.

CLASSIFICATION OF LOCOMOTIVES

Engines..... 42	Simple expansion..... 19	2-cylinder, simple expansion..... 18	Saturated steam.... 2 = 4.76%		
			Steam dryer..... 0		
			Superheated steam.. 16 = 38.10%		
		4-cylinder, simple expansion..... 1	Saturated steam.... 0		
			Steam dryer..... 0		
			Superheated steam.. 1 = 2.37%		
	Compound..... 23	2-cylinder, compound..... 5	Saturated steam.... 3 = 7.14%		
			Steam dryer..... 2 = 4.76%		
			Superheated steam.. 0		
		4-cylinder, compound..... 18	Saturated steam.... 11 = 26.20%		
			Steam dryer..... 1 = 2.37%		
			Superheated steam.. 6 = 14.30%		

A survey of the output of locomotive engineers in various quarters does not indicate that the science of steam-locomotive design has yet attained to that unanimity of expression — that perfection—which shows nothing more requires to be done except make way gracefully and with more or less haste for some younger and more vigorous rival. "Threatened men live long," but the steam locomotive survives because it happens to be a machine which is peculiarly well adapted to the work it has to do; whatever may happen to particular cases, it seems probable that the bulk of the world's land haulage will be done by it for some time to come.

TABLE OF DIMENSIONS, ETC.

10-WHEEL-COUPLED ENGINES.

	Figure 1.	Figure 2.	Figure 3.	Figure 4.	Figure 5.	Figure 6.
Builder	Berlin Engine-building Co.	Berlin Engine-building Co.	Saxon Engine Works.	Nydqvist & Holm.	Esslingen Engine Works.	Borsig.
Type	Tank, 2-cylinder, Schmidt Superheater.	Tank, 2-cylinder, Schmidt Superheater.	Tank, 2-cylinder, Schmidt Superheater.	2-cylinder, Simple Schmidt Superheater.	2-cylinder, Compound.	2-cylinder, Compound.
Cylinder dimensions	24 x 26″	$24^{13}/_{16}$ x 26″	$24^{3}/_{8}$ x $24^{7}/_{8}$″	$27^{9}/_{16}$ x $25^{3}/_{16}$″	$22^{1}/_{4}$ x $33^{7}/_{8}$″ x $24^{3}/_{32}$″	$22^{1}/_{16}$ x $33^{1}/_{2}$ x $24^{7}/_{8}$″
Valves and gear, H. P.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Slide Walschaert.
Valves and gear, L. P.	.....	.....	.....	.....	Walschaert.	Slide Walschaert.
Boiler pressure, pounds per square inch	170	170	170	170	215	200
Maximum tractive force, tons	15.7	17.0	17.3	21.4	13.3	12.2
Length over buffers	41′ $0^{1}/_{8}$″	42′ $7^{13}/_{16}$″	.....	65′ $1^{1}/_{2}$″	55′ $9^{5}/_{16}$″	56′ $11^{1}/_{2}$″
Length, engine wheel base	19′ $0^{3}/_{8}$″	20′ 4″	18′ $4^{1}/_{2}$″	19′ $0^{3}/_{8}$″	18′ $4^{1}/_{2}$″	18′ $4^{1}/_{2}$″
Length, coupled wheel base	19′ $0^{3}/_{8}$″	20′ 4″	18′ $4^{1}/_{2}$″	19′ $0^{3}/_{8}$″	18′ $4^{1}/_{2}$″	18′ $4^{1}/_{2}$″
Length, fixed coupled wheel base	9′ $6^{3}/_{16}$″	10′ 2″	9′ $2^{1}/_{4}$″	9′ $6^{3}/_{16}$″	9′ $2^{1}/_{4}$″	9′ $2^{1}/_{4}$″
Height, rail to boiler center	8′ $4^{3}/_{8}$″	.....	.....	8′ $10^{3}/_{16}$″	8′ $6^{3}/_{8}$″	8′ $10^{5}/_{16}$″
Height, rail to chimney	13′ $11^{3}/_{4}$″	.....	.....	14′ $1^{5}/_{16}$″	15′ $3^{1}/_{16}$″	13′ $11^{3}/_{4}$″
Coupled wheels, diameter	4′ $5^{5}/_{32}$″	4′ $5^{5}/_{32}$″	4′ $0^{3}/_{4}$″	4′ $3^{3}/_{16}$″	4′ $1^{7}/_{32}$″	4′ $3^{13}/_{16}$″
Weight, engine light, tons	58.0	64.8	60.0	75.3	66.6	59.4
Weight, engine loaded, tons	72.4	84.0	77.0	83.6	73.8	66.0
Weight on coupled wheels, tons	72.4	84.0	77.0	83.6	73.8	66.0
Weight, tender, light, tons	.....	.....	.....	20.9	15.5	17.12
Weight, coal, tons	1.97	3.45	2.2	3.94	7.38	7.88
Weight, water, tons	6.9	9.85	7.37	19.7	14.75	11.8
Weight, engine and tender loaded, tons	.....	.....	.....	128.74	111.43	102.8
Firebox, type	Round top between frames.	Round top between frames.	Belpaire between frames.	Round top over frames.	Round top over frames.	Round top over frames
Firebox, grate area, square feet	24.2	29.0	24.3	34.8	30.5	37.2
Boiler, length between tube-plates	14′ $9^{1}/_{8}$″	14′ $9^{1}/_{8}$″	14′ $9^{1}/_{8}$″	15′ 9″	15′ 5″	14′ $9^{1}/_{8}$″
Boiler, average inside diameter	5′ 1″	5′ 1″	.....	5′ $10^{7}/_{8}$″	5′ $4^{3}/_{16}$″	5′ 3″
Tubes, number small	150 of 1.8″	133 of 2″	132 of 1.97″	193 of 1.97″	*153 of $2^{3}/_{4}$″	262 of 2″
Tubes, number large	21 of 5.24″	24 of $5^{1}/_{4}$″	24 of 5″	30 of 5.12″	.....	.....
Superheater, type	Schmidt smoke tube.	Schmidt smoke tube.	Schmidt smoke tube.	Schmidt smoke tube.	.....	.....
Superheater, number of elements	21	24	24	30	.....	.....
Heating surface, firebox, square feet	123.5	147.0	130.0	140.0	.....	129
Heating surface, tubes, square feet	1328.0	1370.0	1763.0	1970.0	.....	2034
Heating surface, total square feet	1451.5	1517	1893.0	2110.00	*2,960	2163
Superheating surface, square feet	442.0	475	443.0	634.0	.....	.....
Ratio, L. P. to H. P., cylinder volume	.....	.....	.....	.....	2.32	2.3
Ratio, loaded to empty engine weight	1.25	1.29	1.28	1.11	1.11	1.11
Ratio, adhesive to total weight	1	1	1	1	1	1
Ratio, adhesion to maximum tractive force	4.48 max. 4.03 min.	4.88 max. 4.55 min.	4.45 max. 3.9 min.	3.9	5.56	5.4
Ratio, heating surface to grate area	60.0	52.0	78.0	62.2	*96.3	58.2
Ratio, heating to superheating surface	3.29	3.18	4.28	3.32	.....	.....

* Serve tubes.

	10-WHEEL-COUPLED ENGINES.			8-WHEEL-COUPLED GOODS ENGINES		
	Figure 7.	Figure 5A	2-10-0 Argentine Great Western Ry.	Figure 8.	Figure 9.	Figure 10.
Builder	Saxon Engine Works.	Ernesto Breda, Milan.	Stephenson & Co., Ltd.	Berlin Engine-building Co.	Henschel & Son.	Nydquist & Holm.
Type	2-cylinder, compound.	4-cylinder, balanced compound.	2-cylinder, simple.	2-cylinder, simple, 3′ 1.4″ gauge.	2-cylinder, simple, superheater.	2-cylinder, simple, superheater.
Cylinder dimensions	23¼ x 33⅞ x24⅞	14.76 x 24.0″ x25.59″	19½ x 28″	16.14 x 20.47″	23.62 x 24.8″	21.62 x 25.19″
Valves and gear, H. P.	Piston Walschaert.	Piston Walschaert.	Balanced flat Walschaert.	Balanced flat Walschaert.	Piston Walschaert.	Walschaert.
Valves and gear, L. P.	Flat Walschaert.	Piston Walschaert.	.....	.....	.....	.....
Boiler pressure, pounds per square inch	185	228	180	200	170	142
Maximum tractive force tons	12.0	13.95	15.1	8.1	14.75 Engine	11.25
Length over buffers	.....	67′ 5.6″	61′ 6¾″	29″ 6.33″	36′ 10.9″	.....
Length, engine wheel base	18′ 4½″	19′ 8.22″	27′ 2″	12′ 3.64″	23′ 7.47″	15′ 11″
Length, coupled wheel base	18′ 4½″	19′ 8.22″	19′ 0″	12′ 3.64″	14″ 9.17″	15′ 11″
Length, fixed coupled wheel base	9′ 2¼″	9′ 10.11″	.....	8′ 2.43″	9′ 10.1″	.....
Height, rail to boiler center	8′ 8 5/16″	9′ 2.44″	9′ 0″	7′ 0.65″	9′ 4.21″	.....
Height, rail to chimney	15′ 0″	13′ 9.95″	14′ 0″	12′ 5″	14′ 0.9″	.....
Coupled wheels, diameter.	4′ 0¾″	4′ 5.54″	4′ 3″	3′ 7.9″	4′ 5.15″	4′ 2.19″
Weight, engine light, tons.	62.0	63.7	.....	36.7	58.0	.....
Weight, engine loaded tons	70.0	73.6 max. 69.75 min.	79.5	47.4	69.75	49.0
Weight on coupled wheels, tons	70.0	73.6 max. 69.75 min.	70.85	47.3 to 40.5	58.5 to 54.25	49.0
Weight, tender, light, tons.		12.8				
Weight, coal, tons		3.94 (on engine.)	670 cubic feet.	.....	17.9	.....
Weight, water, tons		12.8	17.85	1.77	4.92	2.95
Weight, engine and tender loaded, tons		99.2	124.85	5.42	15.75	8.55
Firebox, type	Belpaire over frames.	Round top wide.	Belpaire between frames.	..... Wide over wheels.	103.4 Round top over frames.	..... Round top.
Firebox, grate area, square feet	35.0	37.7	36.0	16.15	32.3	24.0
Boiler, length between tube-plates	15′ 5″	16′ 10.75″	15′ 0″	11′ 7.75″	16′ 4.85″	.....
Boiler, average inside diameter	.....	5′ 2.21″	5′ 3″	4′ 2.39″	5′ 2.05″	.....
Tubes, number small	282 of 1.97″	273 of 2.05″	286 of 2″	.....	.....	.....
Tubes, number large	.....	.....	.....	.....	21	.....
Superheater, type	Intermediate, between H. P. & L.P. Cylinder.	.....	.....	.....	Schmidt.	Schmidt.
Superheater, number of elements	25 smoke tubes.	.....	.....	.....	21	.....
Heating surface, firebox, square feet	142.0	134.5	194.0	60.4	138	.....
Heating surface, tubes, square feet	2005.0	2257	2246.0	1008	1600	.....
Heating surface, total square feet	2147.0	2392	2440.0	1068.4	1738	1364
Superheating surface, square feet	(Estimated) §183.0	.....	.....	.....	430	360
Ratio, L. P. to H. P., cylinder volume	2.13	2.55	.....	.....	.....	.....
Ratio, loaded to empty engine weight	1.13	1.16 max. 1.095 min.		1.29	1.18 max. 1.12 min.	.....
Ratio, adhesive to total weight	1	1	.89	1	.85 max. .836 min.	1
Ratio, adhesion to maximum tractive force	5.7	5.26 max. 4.98 min.	4.7	5.85 max. 4.97 min.	3.94 max. 3.66 min.	4.35
Ratio, heating surface to grate area	61.0	63.6	67.7	66.2	51.7	57.0
Ratio, heating to superheating surface	11.7	.....	.....	.....	4.0	3.8

	8-WHEEL-COUPLED GOODS ENGINES			6-WHEEL-COUPLED GOODS ENGINES.		
	FIGURE 11.	FIGURE 12.	FIGURE 13.	FIGURE 13A.	FIGURE 14.	FIGURE 15.
Builder	Swiss Locomotive & Engine Co., Winterthur.	Henschel & Son.	J. A. Maffei.	Berlin Engine-building Co.	Hannover Engine Building Co.	Société Alsacienne. (Belfort)
Type	4-cylinder, divided and balanced, compound.	2-cylinder, compound.	4-cylinder, balanced, compound.	2-cylinder, simple Schmidt superheater.	4-cylinder, compound, divided and balanced.	4-cylinder, compound, divided and balanced.
Cylinder dimensions	14.57 x 23.62″ x 25.2″	19.29 x 29.53 x 27.56″	15.55 x 25.0 x 25.2″	16.93 x 24.02	15.35 x 25.2 x 25.6″	15.35 x 25.2 x 25.6″
Valves and gear, H. P.	Piston, Walschaert.	Piston, Walschaert.	Both valves on same spindle and worked off the L.P. gear.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.
Valves and gear, L. P.	Balanced trick, worked off H. P.	Piston, Walschaert.		.....	Flat.	Flat.
Boiler pressure, pounds per square inch	200	228	228	170	228	228
Maximum tractive force, tons	11.9	11.27	15.0	7.12	11.3	10.75
		Engine,	Engine,			
Length over buffers	59′ 10.5″	36′ 0.9″	37′ 6″	49′ 3″	62′ 10.84″	68′ 4.3″
Length, engine wheel base	24′ 7.28″	23′ 11.4″	24′ 5.3″	21′ 3.9″	34′ 5.4″	35′ 1.3″
Length, coupled wheel base	16′ 6.82″	15′ 5.04″	15′ 9″	13′ 1.48″	12′ 9.54″	13′ 5.42″
Length, fixed coupled wheel base	10′ 7.95″	9′ 10.11″	10′ 9.92″	13′ 1.48″	12′ 9.54″	13′ 5.42″
Height, rail to boiler center	8′ 6.36″	9′ 2.24″	.....	7′ 3″	9′ 3.25″	9′ 4.21″
Height, rail to chimney	14′ 4.05″	13′ 11.32″	.....	13′ 1.48″	14′ 3¼″	.....
Coupled wheels, diameter	4′ 4.36″	4′ 5.94″	4′ 5.15″	4′ 7.28″	6′ 0.84″	6′ 4.77″
Weight, engine light, tons	58.7	58.2	69.4	41.3	80.5	81.5
Weight, engine loaded, tons	65.2	65.0	75.8	44.8	89.0	88.9
Weight on coupled wheels, tons	56.7	55.5	63.0	36.4	51.5	51.7
Weight, tender, light, tons	16.9	14.1	21.15	13.3	1.97	19.7
Weight, coal, tons	4.92	4.92	6.88	3.44	5.9	5.9
Weight, water, tons	16.7	11.82	19.7	10.8	19.7	19.7
Weight, engine and tender loaded, tons	103.72	95.84	123.53	72.4	134.3	134.2
Firebox, type	Round top between frames.	Round top over frames.	Round top over frames.	Round top between frames	Belpaire, partly between and over frames.	Belpaire, partly between and over frames.
Firebox, grate area, square feet	25.8	30.25	40.3	19.3	46	46
Boiler, length between tube-plates	13′ 9.36″	16′ 4.85″	.....	12′ 8″	19′ 4.375″	19′ 4.375″
Boiler, average inside diameter	4′ 9.09″	4′ 11.06″	.....	4′ 6.56″	5′ 6.14″	5′ 6.14″
Tubes, number small	242 of 1.97″	244 of 1.97″	340 of 1.97″	106 of 1.9″	261 of 2.16″	261 of 2.16″
Tubes, number large	.....	.....	.....	15	.....	.....
Superheater, type	.....	.....	Pielock type steam dryer.	Schmidt.	.....	.....
Superheater, number of elements	.....	.....	340, continuation of boiler tubes.	15	.....	.....
Heating surface, firebox, square feet	153	136	140	95.5	165.5	165.5
Heating surface, tubes, square feet	1722	2020	1960	821	2600	2600
Heating surface, total square feet	1875	2156	2100	916.5	2765	2765
Superheating surface, square feet	.....	.....	538	242	.....	.....
Ratio, L. P. to H. P., cylinder volume	2.8	2.34	2.59	.....	2.68	2.68
Ratio, loaded to empty engine weight	1.15	1.09	1.12	1.08	1.1	1.09
Ratio, adhesive to total weight	.87	.855	.845	.81	.578	.582
Ratio, adhesion to maximum tractive force	4.75	4.92	4.2	5.22	4.55	4.8
Ratio, heating surface to grate area	72.5	71.5	52.0	60.0	60.2	60.2
Ratio, heating to superheating surface	.....	.....	3.9	4.8	.....	.....

	SIX-WHEEL-COUPLED, "PACIFIC TYPE."					6-WHEEL-COUPLED 2-6-2 TYPE.
	FIGURE 20.	FIGURE 16.	FIGURE 17.	FIGURE 18.	FIGURE 19.	FIGURE 21.
Builder	Western of France Ry., Rouen (Sotteville.)	J. A. Maffei.	J. A. Maffei.	Esslingen Engine Works.	Société Alsacienne. (Grafenstaden)	Berlin Engine-building Co. and Ernesto Breda.
Type	4-cylinder, divided and balanced compound.	4-cylinder, compound, balanced Schmidt superheater.	4-cylinder, compound, balanced Schmidt superheater.	4-cylinder, compound, balanced Schmidt superheater.	4-cylinder, compound, divided and balanced Schmidt superheater.	4-cylinder, balanced compound.
Cylinder dimensions	15.75 x 26.0 x 25.2"	16.72 x 24 x 25.6 x 26.4"	16.72 x 24 x 25.6 x 26.4"	16.53 x 24.41 x 24.1"	14.96 x 23.62 x 25.98"	14.17 x 23.23 x 25.6"
Valves and gear, H. P.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.
Valves and gear, L. P.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	.....	Piston Walschaert.
Boiler pressure, pounds per square inch	228	213	228	213	213	228
Maximum tractive force, tons	11.3	11.16	12.35	9.53	8.6	9.62
Length over buffers	.....	70' 2.36"	69' 3.93"	67' 0.33"	69' 10.6"	64' 5"
Length, engine wheel base	34' 8.14"	37' 3.44"	36' 9.34"	36' 2.6"	33' 11.5"	27' 8.7"
Length, coupled wheel base	13' 3.06"	13' 2.27"	12' 8.76"	12' 5.6"	14' 1.3"	12' 11.5"
Length, fixed coupled wheel base	13' 3.06"	13' 2.27"	12' 8.76"	12' 5.6"	14' 1.3"	6' 4.77"
Height, rail to boiler center	9' 6.17"	.....	9' 3.1"	9' 6.17"	9' 3"	9' 2.24"
Height, rail to chimney	14' 1.3"	.....	15' 3.07"	15' 2.68"	13' 10.93"	13' 11.52"
Coupled wheels, diameter	6' 4.38"	6' 1.62"	5' 10.87"	5' 10.87"	6' 8.32"	6' 0.84"
Weight, engine light, tons	81.5	77.25	78.6	74.6	74.3	63.25
Weight, engine loaded, tons	90.7	85.2	87.0	83.6	81.3	70.0
Weight on coupled wheels, tons	53.55	47.2	50.2 max. 47.0 min.	46.8	47.2	44.6
Weight, tender, light, tons	23.6	20.2	21.15	21.15	21.0	14.75
Weight, coal, tons	8.8	7.38	6.9	5.41	5.9	5.9
Weight, water, tons	23.8	25.6	19.7	19.7	20.7	19.7
Weight, engine and tender loaded, tons	146.9	138.4	134.75	129.86	128.9	110.35
Firebox, type	Belpaire wide.	Round top over frames.	Round top over frames.	Round top over frames, 2 fire doors.	Belpaire. between frames	Belpaire wide.
Firebox, grate area, square feet	43.04	48.4	48.4	43.6	34.6	37.7
Boiler, length between tube-plates	19' 8.12"	.....	16' 8.8"	18' 0.54"	14' 1.3"	16' 10.75"
Boiler, average inside diameter	5' 3.47"	.....	5' 6.93"	5' 6.41"	5' 3"	5' 1.73"
Tubes, number small	283 of 2.16"	.....	175 plain and 5 stay tubes.	174 of 2.04"	92 serve 2.76"	273 of 2.05",
Tubes, number large	.....	.....	25	24 of 5.24"	.....	.....
Superheater, type	.....	Schmidt.	Schmidt.	Schmidt.	Schmidt.	.....
Superheater, number of elements	.....	.....	25	24	.....	.....
Heating surface, firebox, square feet	150	157	158	161.5	187	127
Heating surface, tubes, square feet	2894	2191	2088	2077	1968	2234
Heating surface, total square feet	3044	2348	2246	2239	2055	2361
Superheating surface, square feet	.....	538	538	570	414	.....
Ratio, L. P. to H. P., cylinder volume	2.72	2.56	2.56	2.22	2.5	2.68
Ratio, loaded to empty engine weight	1.11	1.1	1.1	1.12	1.09	1.11
Ratio, adhesive to total weight	.59	.555	.580 max. .545 min.	.56	.545	.64
Ratio, adhesion to maximum tractive force	4.74	4.22	4.13 max. 3.82 min.	4.94	5.5	4.64
Ratio, heating surface to grate area	70.7	48.6	46.5	52.6	62.2	62.7
Ratio, heating to superheating surface	.....	4.37	4.18	3.92	5.2	.....

6-WHEEL-COUPLED PASSENGER ENGINES.

	Figure 22.	Figure 23.	Figure 24.	Figure 25.	Figure 26.	Figure 27.
Builder	Henschel & Son.	Henschel & Son.	Henschel & Son.	Borsig.	Soc. Anonyme. Franco-Belge.	Saxon Engine Works.
Type	4-cylinder, compound, divided and balanced.	4-cylinder, divided and balanced compound Schmidt superheater.	4-cylinder, divided and balanced compound Schmidt superheater.	4-cylinder, divided and balanced compound.	4-cylinder, simple balanced Schmidt superheater.	2-cylinder, simple, Schmidt superheater.
Cylinder dimensions	13.39 x 22.05 x 25.2″	14.96 x 21.65 x 25.2″	14.57 x 21.26 x 25.6″	13.39 x 21.26 x 25.6″	17.52 x 25.2″	2.40 x 24.8″
Valves and gear, H. P.	Flat Walschaert.	Piston Walschaert.	Piston Walschaert.	Flat Walschaert.	Piston Walschaert.	Piston Walschaert.
Valves and gear, L. P.	Flat Walschaert.	Piston Walschaert.	Piston Walschaert.	Flat trick Walschaert.	.....	.....
Boiler pressure, pounds per square inch	227	213	227	213	200	170
Maximum tractive force, tons	7.98	7.35	7.46	8.44	13.23	11.0
Length over buffers	Engine, 37′ 11.5″	Engine, 37′ 11.5″	Engine, 39′ 3.26″	.....	60′ 2.85″	65′ 0½″
Length, engine wheel base	26′ 6.9″	26′ 11.6″	27′ 11.83″	25′ 10.44″	28′ 6.9″	28′ 4.56″
Length, coupled wheel base	14′ 5.23″	14′ 1.3″	15′ 8.2″	12′ 10.73″	13′ 11.7″	13′ 5.42″
Length, fixed coupled wheel base	14′ 5.23″	14′ 1.3″	15′ 8.2″	12′ 10.73″	13′ 11.7″	13′ 5.42″
Height, rail to boiler center	8′ 6.36″	8′ 3.21″	8′ 6.36″	8′ 1.24″	9′ 3″	9′ 2.2″
Height, rail to chimney	13′ 11.32″	14′ 1.3″	13′ 11.75″	14′ 0.11″	14′ 0.51″	14′ 0.51″
Coupled wheels, diameter	6′ 5.95″	6′ 4.38″	6′ 6.74″	5′ 5.35″	6′ 5.95″	6′ 2.22″
Weight, engine light, tons	61.0	63.5	66.4	56.5	72.8	62.5
Weight, engine loaded, tons	67.5	69.0	72.3	61.5	80.0	69.8
Weight on coupled wheels, tons	47.2	49.5	49.5	.....	52.5	47.2
Weight, tender, light, tons	22.3	.....	.....	.....	21.5	19.7
Weight, coal, tons	4.92	.....	.....	.....	5.9	5.0
Weight, water, tons	20.65	.....	.....	.....	19.7	20.3
Weight, engine and tender loaded, tons	115.37	.....	.....	.....	127.1	114.8
Firebox, type	Belpaire between frames.	Belpaire between frames.	Belpaire between frames.	Round top between frames.	Round top between frames.	Belpaire between frames.
Firebox, grate area, square feet	29.6	29.6	32.3	29.9	34.2	30.6
Boiler, length between tube-plates	13′ 9.36″	14′ 9.2″	13′ 1.5″	11′ 1.9″	13′ 1.5″	14′ 11.15″
Boiler, average inside diameter	4′ 9.9″	4′ 7.6″	4′ 10.4″	4′ 11″	5′ 3.6″	5′ 5″
Tubes, number small	232 of 1.97″	22 plain, 2.05″ 52 serve, 2.76″	19 plain, 1.97″ 64 serve, 2.76″	150 serve, of 2.56″	180 of 1.97″	180 of 1.97″
Tubes, number large	.....	21 of 5″	21 of 5″	.....	27 of 5″	24 of 5.24″
Superheater, type	.....	Schmidt.	Schmidt.	.....	Schmidt.	Schmidt.
Superheater, number of elements	.....	21	21	.....	27	24
Heating surface, firebox, square feet	153	146	167	134	177	143.6
Heating surface, tubes, square feet	1480	1309	1480	1906	1496	1691
Heating surface, total square feet	1633	1455	1650	2040	1673	1834
Superheating surface, square feet	.....	411	361	.....	407	504
Ratio, L. P. to H. P., cylinder volume	2.72	2.1	2.13	2.52	.....	.....
Ratio, loaded to empty engine weight	1.1	1.09	1.09	1.09	1.1	1.12
Ratio, adhesive to total weight	.70	.717	.685	.....	.656	.635
Ratio, adhesion to maximum tractive force	5.9	6.73	6.64	.....	3.96	4.28
Ratio, heating surface to grate area	55.0	49.0	55.0	76.5	48.8	60.2
Ratio, heating to superheating surface	.....	3.56	4.91	.....	4.11	3.64

	6-WHEEL-COUPLED PASSENGER ENGINES				6-WHEEL-COUPLED TANK ENGINES.	
	FIGURE 28.	FIGURE 29.	FIGURE 30.	FIGURE 31.	FIGURE 32.	FIGURE 33.
Builder	Berlin Engine-building Co.	Berlin Engine-building Co.	Henschel & Son.	Beyer Peacock & Co., Ltd.	Hannover Engine Building Co.	Société Alsacienne (Belfort)
Type	2-cylinder, simple, Schmidt superheater.	2-cylinder, simple, Schmidt superheater.	2-cylinder, simple, Schmidt superheater.	2-cylinder, simple.	4-cylinder, divided and balanced compound.	4-cylinder, balanced compound.
Cylinder dimensions	23.23 x 24.8″	21.25 x 27.56″	21.26 x 24.8″	19 x 26″	14.57 x 22.83 x 25.59″	13.39 x 20.87 x 23.62″
Valves and gear, H. P.	Piston Walschaert.	Piston, trick Walschaert.	Piston Walschaert.	Flat balanced Walschaert.	Piston Walschaert.	Piston Walschaert.
Valves and gear, L. P.	.....	.....	.....	.....	Piston Walschaert.	Piston Walschaert.
Boiler pressure, pounds per square inch	170	170	170	200	228	212
Maximum tractive force, tons	11.1	9.76	10.16	8.07	10.35	8.07
Length over buffers	Engine, 36′ 8.9″	54′ 6.1″	58′ 10.5″	.....	52′ 0″	39′ 4.4″
Length, engine wheel base	27′ 4.75″	22′ 1.75″	21′ 1.94″	26′ 9″	39′ 9.56″	28′ 10.46″
Length, coupled wheel base	15′ 0.32″	13′ 9.36″	13′ 1.5″	13′ 11″	13′ 4.62″	14′ 9.17″
Length, fixed coupled wheel base	15′ 0.32″	7′ 4.6″	6′ 6.75″	13′ 11″	13′ 4.62″	14′ 9.17″
Height, rail to boiler center	9′ 0.25″	8′ 11.5″	8′ 4.4″	9′ 0″	8′ 6.62″	8′ 6.36″
Height, rail to chimney	13′ 11.75″	13′ 11.32″	13′ 11.75″	.....	13′ 11.75″	.....
Coupled wheels, diameter	5′ 8.9″	6′ 0.84″	5′ 3″	6′ 6″	5′ 5.37″	5′ 0.63″
Weight, engine light, tons	62.6	48.2	53.1	.....	83.65	59.1
Weight, engine loaded, tons	68.75	54.2	58.6	57.8	98.55	73.1
Weight on coupled wheels, tons	47.2	43.6	45.0	40.68	48.75	50.3
Weight, tender, light, tons	23.2	13.3	21.9	.....	.....	.....
Weight, coal, tons	5.42	4.92	4.92	5.5	2.95	2.48
Weight, water, tons	21.2	14.75	15.75	15.6	8.85	6.88
Weight, engine and tender loaded, tons	118.57	87.17	101.17	95.8	.....	.....
Firebox, type	Round top between frames.	Round top between frames.	Round top between frames.	Belpaire between frames.	Belpaire between frames.	Belpaire between frames.
Firebox, grate area, square feet	28.0	26.5	24.25	28.0	33.0	27.1
Boiler, length between tube-plates	15′ 5″	13′ 1.5″	14′ 9.2″	13′ 4.62″	13′ 11.37″	12′ 9.54″
Boiler, average inside diameter	5′ 3″	4′ 10.47″	4′ 11″	4′ 7″	5′ 1″	4′ 8.92″
Tubes, number small	139 of .197″	116 of .197″	152 of 1.8″	228 of 1.87″	146 serve of 2.56″	117 serve of 2.76″
Tubes, number large	24 of 5.24″	21 of 5.24″	21 of 5.24″	.....	.....	.....
Superheater, type	Schmidt.	Schmidt.	Schmidt.	.....	.....	.....
Superheater, number of elements	24	21	21	.....	.....	.....
Heating surface, firebox, square feet	157	106.6	116	146	171	135
Heating surface, tubes, square feet	1464	1059	1347	1498	2490	1793
Heating surface, total square feet	1621	1116	1463	1644	2661	1928
Superheating surface, square feet	532	361	443	.....	.....	.....
Ratio, L. P. to H. P., cylinder volume	.....	.....	.....	.....	2.46	2.43
Ratio, loaded to empty, engine, weight	1.1	1.12	1.1	.....	1.18	1.23
Ratio, adhesive to total weight	.687	.8	.77	.705	.495	.69
Ratio, adhesion to maximum tractive force	4.26	4.45	4.44	5.04	4.7	6.25 max. 5.4 min.
Ratio, heating surface to grate area	58.0	44.0	60.5	58.7	64.4	71.2
Ratio, heating to superheating surface	3.02	3.24	3.3	.....	.....	.....

	6-WHEEL-COUPLED TANK ENGINES.		4-WHEEL-COUPLED "ATLANTIC" TYPE.		4-WHEEL-COUPLED, 4-4-0 TYPE.	
	FIGURE 34.	FIGURE 35.	FIGURE 36.	FIGURE 37.	FIGURE 38.	FIGURE 39.
Builder	A. Borsig.	Henschel & Son.	Saxon Engine Works.	Hannover Engine Building Co.	Hannover Engine Building Co.	Henschel & Son, Cassel.
Type	2-cylinder, simple, Schmidt superheater.	2-cylinder, simple, Schmidt superheater.	2-cylinder, simple, Schmidt superheater.	4-cylinder, balanced compound.	2-cylinder, compound. Lentz valves.	2-cylinder, simple, Schmidt superheater.
Cylinder dimensions	22.64 x 24.8″	19.68 x 23.62″	20.08 x 24.8″	14.96 x 22.83 x 23.62″	18.11 x 26.77 x 23.62″	21.65 x 24.8″
Valves and gear, H. P.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Piston Walschaert.	Lentz Walschaert.	Piston Walschaert.
Valves and gear, L. P.	.....	.....	.....	Piston Walschaert.	Lentz Walschaert.	.....
Boiler pressure, pounds per square inch	170	170	170	200	170	170
Maximum tractive force, tons	10.52	8.2	7.33	7.02	4.68	8.03
Length over buffers	38′ 8.6″	39′ 2.07″	65′ 4.5″	71′ 7.5″	Engine 34′ 0″	60′ 2.47″
Length, engine wheel base	26′ 2.96″	27′ 2.77″	28′ 6.52″	35′ 3.23″	24′ 4.34″	26′ 2.96″
Length, coupled wheel base	13′ 10.54″	13′ 1.48″	7′ 4.58″	7′ 6.55″	8′ 6.36″	9′ 10.11″
Length, fixed coupled wheel base	13′ 10.54″	13′ 1.48″	7′ 4.58″	7′ 6.55″	8′ 6.36″	9′ 10.11″
Height, rail to boiler center	9′ 2.27″	9′ 0.27″	9′ 3.24″	8′ 9.37″	8′ 2.5″	9′ 0.27″
Height, rail to chimney	13′ 11.72″	13′ 7.78″	14′ 0.51″	13′ 8.75″	13′ 9.37″	13′ 11.92″
Coupled wheels, diameter	5′ 8.9″	5′ 3.78″	6′ 5.95″	6′ 5.95″	5′ 8.9″	6′ 10.68″
Weight, engine light, tons	59.7	51.8	61.0	67.25	47.5	53.2
Weight, engine loaded, tons	74.9	65.0	68.4	73.5	53.0	58.75
Weight on coupled wheels, tons	47.8	41.3	31.5	32.5	30.0	33.4
Weight, tender, light, tons	.....	.....	19.7	24.9	21.35	23.2
Weight, coal, tons	2.46	1.47	5.0	9.05	4.92	6.9
Weight, water, tons	7.38	6.4	20.6	30.7	19.7	21.1
Weight, engine and tender loaded, tons	.....	.....	113.7	136.5	100.5	110.0
Firebox, type	Round top between frames.	Belpaire between frames.	Belpaire between frames.	Round top wide.	Round top between frames.	Round top between frames.
Firebox, grate area, square feet	19.9	25.8	30.7	43.0	24.4	24.6
Boiler, length between tube-plates	14′ 7.2″	12′ 1.67″	14″ 11.14″	17′ 0.73″	13′ 5.5″	14′ 9.17″
Boiler, average inside diameter	4′ 10.47″	4′ 7.7″	5′ 4.37″	*5′ 3.07″	4′ 6.72″	4′ 10.57″
Tubes, number small	150 of 1.81″	63 serve, 2.56″ 16 plain, 1.97″	180 of 1.97″	264 of 2.16″	247 of 1.62″	156 of 1.8″
Tubes, number large	21 of 5.24″	21 of 5.24″	24 of 5.27″	.....	Steam dryer 46 of 1.8″	21 of 5.24″
Superheater, type	Schmidt.	Schmidt.	Schmidt.	.....	Ranapier intermediate steam dryer.	Schmidt.
Superheater, number of elements	21	21	24	.....	46	21
Heating surface, firebox, square feet	113	121	145	151	.....	136
Heating surface, tubes, square feet	1333	1209	1691	2391	.....	1363
Heating surface, total square feet	1446	1330	1836	2542	1285	1499
Superheating surface, square feet	437	349	504	.....	Steam dryer 151	402
Ratio, L. P. to H. P., cylinder volume	.....	.....	.....	2.33	2.19	.....
Ratio, loaded to empty, engine, weight	1.26	1.25	1.12	1.09	1.11	1.11
Ratio, adhesive to total weight	.64	.63	.46	.443	.567	.568
Ratio, adhesion to maximum tractive force	4.55 max. 3.7 min.	4.92 max. 4.5 min.	4.3	4.63	6.42	4.15
Ratio, heating surface to grate area	72.6	51.7	60.2	5.9	52.6	60.8
Ratio, heating to superheating surface	3.32	3.8	3.6	.....to drying surface	8.5	3.73

* In parallel coarse.

OIL BURNING ON FREIGHT LOCOMOTIVES

By H. B. MacFarland

IN the distribution of natural resources, Nature has not given the equitable distribution of fuel supplies that insures uniform cost of power throughout a vast nation. A study of the maps prepared by the United States Geological Survey showing distribution of fuel beds in America reveals the fact that enormous quantities of fuel are located at irregular intervals throughout the country.

In one part of the United States we find beds of hard coal, in another bituminous coal, at other locations we have gas, lignites, or fuel oil. Owing to this irregularity in distribution, there will always be an increase in cost of power at points furthest removed from the fuel beds. Whether or not one fuel may be used at a given point in preference to another becomes a matter of cost of fuel at the point of production, together with cost of transportation of the fuel to the point of consumption.

There is an immense quantity of coal in the mountainous portions of Colorado and New Mexico. There are vast quantities of oil taken from the different sections of California. In New Mexico little or no oil is used as fuel for power purposes; in California little or no coal is used. At an intermediate point between these two a division will be found where the cost of producing power, all factors being taken into consideration, will be the same whether coal or oil is used as fuel.

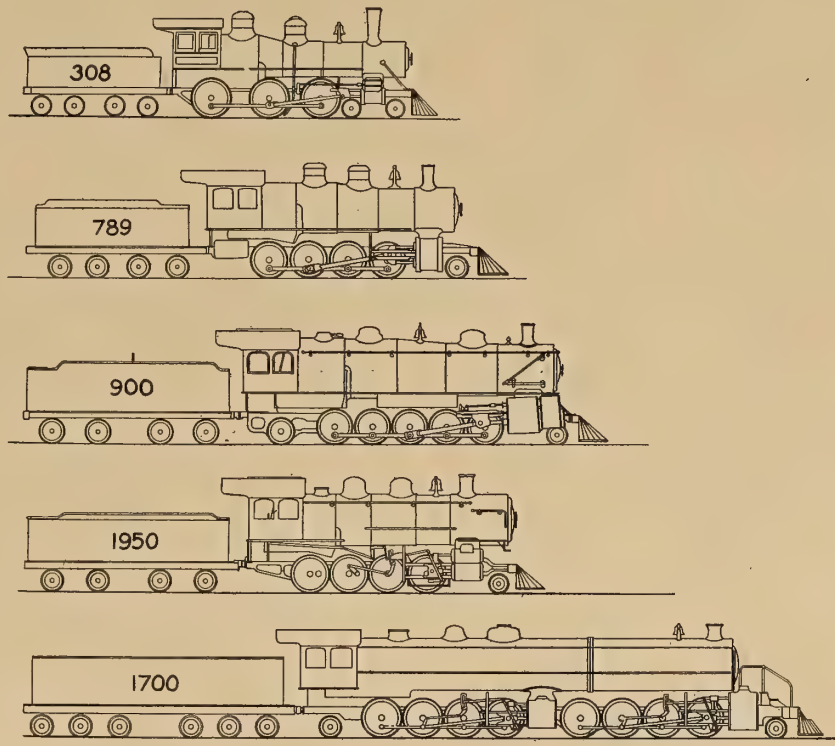
It is the object of this article to present to the public data relative to the burning of oil on freight locomotives. These data have special reference to the burning of oil on the Coast lines of the Santa Fé Railroad.

All locomotives, whether passenger or freight, running between Winslow, Arizona, and San Francisco, Cal., a distance of 913 miles, are oil burners. The locomotives running over the main line from Barstow to Los Angeles, Cal., a distance of 141 miles, are also oil burners, as well as the locomotives running over all branch lines west of Winslow.

During a period of fifteen years or more since oil-burning locomotives have been used on this territory, a great deal of atention has been given to the economic production of power with oil burning. It is not intended, however, to take up in detail the historical development of oil burners, but to give the details of the present system of burning, of storage, of transporting, of distributing, and of accounting for all fuel oil used on this territory.

A great deal of experimental work has been done with many different and ingenious kinds of burners in order to give a more economic evaporation of water from the oil. Many very peculiar and ingenious types and arrangements of brick work and arch chambers have been introduced in order to prevent smoking, to preserve the life of the firebox and the flues, and at the same time to give higher efficiency in the consumption of oil. The experiments of this character have lasted over months and years of time; but in the end the practical conditions of operating locomotives have prevented any complicated arrangement of brick work, although such an arrangement, if practicable, would have given much better economy in the burning of oil

Classes of Oil Burning Locomotives



Size of Cylinders	19"x24"
Boiler Pressure	165lbs
Weight on Drivers	100000
Total Weight	130000
Tractive Force	21300
Size of Cylinders	24"x32"
Boiler Pressure	160lbs
Weight on Drivers	179965
Total Weight	203115
Tractive Force	43800
Size of Cylinders	19&32"x32"
Boiler Pressure	225lbs
Weight on Drivers	234580
Total Weight	287240
Tractive Force	62800
Size of Cylinders	24"x32"
Boiler Pressure	160lbs
Weight on Drivers	183200
Total Weight	212400
Tractive Force	44000
Size of Cylinders	26&38"x34"
Boiler Pressure	220lbs
Weight on Drivers	412350
Total Weight	462350
Tractive Force	108300

FIG. 1.—TYPES OF OIL-BURNING LOCOMOTIVES ON THE ATCHISON, TOPEKA & SANTA FE RAILWAY

than was possible at the given time.

A modern freight locomotive is a monster power plant on wheels. One looks with admiration upon a stationary plant of 2,000 horse-power or more, with its battery of boilers, its smooth-running Corliss engines, and its well-regulated generators, with little conception of the difficulties which are encountered when a plant of such a power as this is in the form of a locomotive, moving over roadbeds, up and down maximum grades of 160 feet per mile, at varying rates of speed. Such a power plant on wheels must carry its fuel and water with it, and may, in the same day, pass from a region where the temperature is 120 degrees to another region where freezing conditions exist. On a trip of this kind nearly all of the machinery is exposed to the wind and weather, to the dust incidental to the motion and velocity of the locomotive, and to the furious and cutting action of sand storms which prevail in certain sections of the country.

The oil-burning engines on the Coast lines of the Santa Fé pass over five mountain ranges. The territory from Winslow, Arizona, to Bakersfield, California, is a mountainous desert. From Seligman, Arizona, to Needles, California, a distance of 150 miles, the change in elevation is over 5,000 feet. In all this territory water conditions are very bad. In many portions of the country water is hauled for many miles in order to supply the engines. These are some of the conditions to which locomotives operating in this territory are subjected on account of the irregularity in the distribution of Nature's resources in fuel and water.

There are on the Santa Fé system 685 oil-burning locomotives in the different classes of service—passenger, switching, helping, local and through freight. Three hundred and seventy-seven of these are in service on the Coast lines, and of these latter 179 locomotives are in through freight service.

No distinction in design is made on the system as to whether an engine is to be a coal or an oil-burning engine. As a matter of fact, engines are frequently changed from one territory to another, and, in consequence, are changed from oil to coal burning according to the kind of fuel used in the different districts. These changes, of course, are not usually made unless an engine is passing through the shop, as considerable cost is involved in changing from a coal to an oil-burning engine.

In Fig. 1 five different types of oil-burning locomotives in through freight service are shown. There are forty-five smaller locomotives of the 308 class and of other classes, twenty-four of the 789 class, ninety-one of the 900 and 1,600 classes, seventeen of the 1950 class and two of the 1700 class.

The 900 and 1600 classes of tandem compound, high-pressure engines have been in heavy mountain service for eight years; the 1950 class of simple superheater, low-pressure engines have had similar service on Tehachapi Mountain for two years; the 1700 class Mallet articulated have only recently been placed in service.

The burners used on all classes of engines are known as the Santa Fé type of Booth burner. It has been demonstrated that there is little economy to be obtained from different types of burners. The economy in the use of oil is to be obtained from a proper method of combustion, the burner serving only as a medium for the supply of oil to the firebox.

The general construction of the Booth burner is shown in Fig. 2. The oil flows through the upper portion of the burner and is delivered through an opening 7-16 inches high by 2½ inches in length. The steam for atomizing is delivered from the lower chamber through a mouthpiece with an opening 1-32 of an inch high and 2¾ inches long. A very important point is that the steam opening should be a little wider than the oil opening. The oil, in flowing

FIG. 2.—THE BOOTH OIL BURNER

through the chambers, naturally gravitates over the mouthpiece and falls on the steam used for atomizing purposes. This steam being delivered at high velocity, carries the oil to the back of the firebox, and on its passage the oil enters into chemical combination with the air.

The best arrangement of burner is known as the front-end arrangement. The burner is placed in the front end of the firebox instead of at the back, as was the practice until a year ago. Oil is supplied to the burner by gravity from a special oil tank so constructed as to fit the coal space on the engine tank.

On account of the viscosity at ordinary temperatures of the heavy oils from the California fields, it is necessary to provide some means of heating the oil in order that it may flow readily to the burner. This is accomplished by what is known as a box heater in the oil tank, whereby a portion of the oil in the tank is heated up to proper temperature just as it leaves the tank. Great irregularity in combustion is found when oil flows at temperatures of 140 degrees or more; much greater uniformity of combustion is found when oil is supplied at temperatures of 90 to 95 degrees.

In the present arrangement with the burner located in the front end of the firebox, there is no necessity for having a brick crown arch, as was necessary in what was known as the back-end burner arrangement. The maintenance of the arch portion of the brick work was an expensive

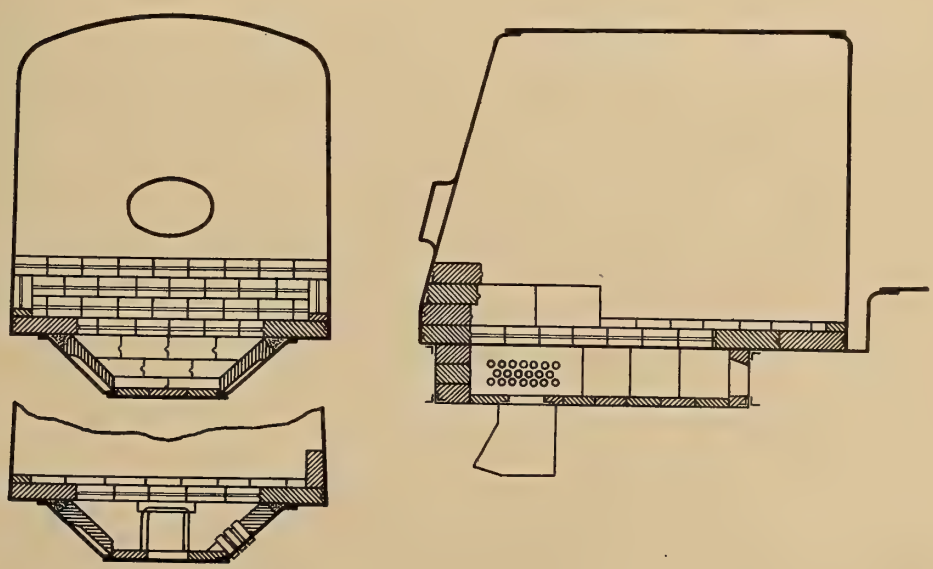


FIG. 3.—ARRANGEMENT OF OIL-BURNING FURNACE

item, and many engine failures have resulted from the arches falling down, due to motion of the locomotive.

Fuller appreciation of this point may be gained by the number of bricks in a firebox with the different types of burners. With the back-end burner arrangement 1,200 bricks are required in the construction of the lining of the fire-pan and the arch chamber. The front-end burner requires only 455 bricks in its construction. The material and labour costs are, of course, proportionate to the number of brick used. There is, of course, some special shape of fire-pan that will give highest efficiency. The front-end burner arrangement allows the construction of a pan that will give high efficiency, on account of the fact that less brick is used in its construction and that greater heating surface of the firebox is exposed to hot gases. The first cost of building and arranging a pan for a back-end burner device is $35 for labour and $44.95 for material. The cost of the latest design of pan with the front-end burner amounts to $25 for labour and $36 for material. This is a reduction of $10 in labour and $8.95 in material, a total saving of $18.95.

Recently the cost for brick work and labour on fireboxes has been greatly reduced, due to the making of special bricks for the boxes. Instead of using ordinary firebricks, involving numerous joints, specially constructed bricks are placed in the bottom and on the sides of the pan, and also on the side walls, so that only about 110 bricks are necessary in a well-designed fire-pan. The shape of the pan and the arrangement of the bricks are shown in Fig. 3. There is also shown in this figure a special arrangement for drawing air into the pan, in order to give more perfect combustion.

When the front-end burner was introduced one of the most difficult problems to contend with was the drumming that occurred in the pan. This drumming was no more than a series of explosions occurring one after the other, due to the improper union of air and oil. When the atomizer was used too hard and the oil was blown to the flash wall in the back of the firebox, only a portion of the oil was burned. With the return of this oil, however, towards the front of the firebox in a highly volatilized condition, it united with air, with the result of an explosion. The constant series of explosions continuously jarred down the brick work, so that it was necessary to have repairs made upon the brick work very frequently and at considerable expense.

In May and June of 1909 very extensive tests were made between Needles, California, and Seligman, Arizona, with a Santa Fé type locomotive. During this series of tests the air inlet tubes were introduced into service and thoroughly tested out. By the use of these tubes the drumming action in the fire-pan was eliminated, more proper combustion of gases was secured and the smoke nuisance entirely eliminated. With the elimination of smoke, there was a consequent reduction of carbon deposited on the flues and, as a result, better steaming engines, with reduced fuel oil consumption.

During these tests the flue gases were analyzed at regular intervals of time, and a very careful checking was made in order to determine the proper number of air inlets on the side of the brick pan so that there would be an elimination of the drumming action and the highest possible efficiency in combustion. The practical problem was a most difficult one, on account of the fact that the engine ran at different rates of speed on different grades, and on this account it was necessary to make a compromise in order to effect maximum economy of combustion.

A further complication in this method of introducing air to the pan was the necessity of keeping down the amount of cool air that might be introduced into the firebox when the

engine was drifting on heavy down grades. When drifting, little oil is used for combustion, and a considerable reduction in the temperature of the firebox, due to the introduction of excess air, is sure to give flue troubles.

At the beginning of the experiment, when a small number of tubes were used on each side, the percentage of carbon dioxide, indicating complete combustion in the flue gases, was only 9.5 per cent.; at the completion of the experiment the efficiency of this mode of combustion was demonstrated by an increase of the carbon dioxide in the flue gases, amounting to 13.4 per cent. The average analysis of the smoke-box gases for a given run is shown in the following figures:

CONSTITUENTS	Per Cent.
Oxygen	2.97
Carbon monoxide	.53
Carbon dioxide	12.53
Nitrogen	83.97

These figures show for road test a very high percentage of carbon dioxide and a small percentage of oxygen, indicating a relatively small coefficient of air dilution.

A very important point to be considered is the time to be saved at round-houses in turning engines, on account of the application of the front-end burner with the new type of brick pan and the smaller number of bricks for this method of arrangement of burner. It is possible to cool off the engine and turn it in three hours less than with the back-end burner. A great many bricks retain their heat for so long a time that it takes some time to cool them off before the boiler men can get inside to do the necessary work. The present arrangement, too, makes available about 14 square feet more heating surface in the firebox than the former arrangement, and, consequently, makes the engine much more valuable as a steam producer, getting more heating surface and better water circulation.

Possibly the greatest advantage of this style of burner and brick pan is the increased life of the firebox itself. With the back-end burner arrangement, the life of the firebox on oil-burning districts was very short, in many cases not being more than one year. With the front-end burner arrangement, the life of the firebox has been increased on engines where applied to three years. The improved air intake tubes will probably give a further increase in the life of the firebox of 30 to 40 per cent., besides an increase in fuel oil economy, decrease in boiler repairs, increase in flue mileage between shoppings and decrease in cost of brick work.

The oil used, for the most part, is obtained from Bakersfield, and has the following characteristics:

Specific gravity, degs. Baume, at 60 degs. F.	14.5
Specific gravity	.969
Flashing point, degs. F.	226
Burning point, degs. F.	277
Water	Trace.
Heat units per pound, calorimeter test	19,337
Weight per barrel of 42 gallons, pounds	336

The theoretical evaporation of this oil, if all heat in the oil were given to evaporation of steam, is 20 pounds of water per pound of oil from and at 212 degrees Fahr.

In actual service conditions on road work 15.3 pounds of water have been evaporated per pound of oil, showing a boiler efficiency of 76 per cent. While this figure is not a high one for stationary practice, yet it is an especially good one for road service where the boiler is not working at full capacity at all times.

Fuel oil is supplied on the Coast lines in four different ways:

1. Bakersfield oil fields supplies all the lines from Richmond, Cal., to Gallup, N. M. There are about 800 tank cars distributing oil to various stations along the line; 35 to 40 are routed out of Bakersfield each day.

2. The Olinda oil fields supply points on the Los Angeles Division, and for this service 60 to 70 tank cars, each holding about 10,000 gallons, are used.

3. The Salt Lake route uses oil on Santa Fé tracks from Los Angeles to Daggett, and replaces the company by their own oils, which are

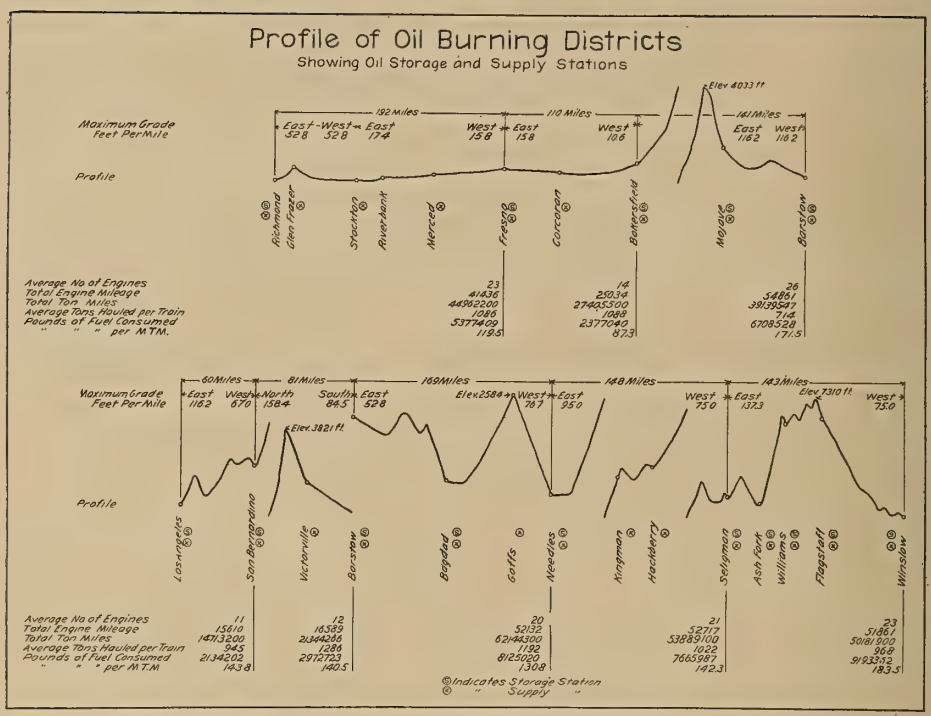


FIG. 4.—OIL-BURNING DISTRICTS ON THE ATCHISON, TOPEKA & SANTA FE RAILWAY

considerably heavier than those used by the Santa Fé.

4. Los Angeles is supplied with oil by an exchange with the Amalgamated, so that oil is run directly from one storage tank to another without transfer in tank cars. An exchange is also established at Bakersfield with the Standard Oil Company, so that oil is taken directly from their storage tank and supplied by pipe line to the company's storage tank at Bakersfield.

There are, in all, seventeen storage tanks on the Coast lines. The greatest storage capacity is at Needles, where the three oil storage tanks have a total capacity of 139,979 barrels. The capacity of the principal tanks is shown in the opposite table.

In Fig. 4 is shown a profile of the oil-burning districts; also, the oil storage and the supply stations. The number of miles between division points is also indicated in this figure, as well as the maximum grades east and west and some of the principal elevations of points on the line. Further data shown in Fig. 4 for each division has reference to the average number of engines in through freight service, the total engine mileage, the total ton-miles, the average tons hauled by trains, the total pounds of fuel consumed, and the pounds of fuel consumed per thousand ton-miles. These data are taken from the report of fuel performance of engines for the month of December, 1909. During this month fuel

STORAGE TANKS ON COAST LINES

Location	Capacity in Bbls.
Los Angeles	33,965
San Bernardino, No. 1	37,341
San Bernardino, No. 2	37,341
Richmond	54,921
Fresno	6,076
Bakersfield	5,555
Mojave	6,097
Barstow (concrete)	47,022
Bagdad	37,341
Needles, No. 1 (west conc. res.)	50,175
Needles, No. 2 (east conc. res.)	45,985
Needles, No. 3 (steel)	36,820
Seligman	50,677
Williams	27,222
Ash Fork	25,788
Flagstaff	40,856
Winslow	27,127

oil was issued by the fuel department for all classes of service, passenger, freight, switch, etc., aggregating 313,988 barrels, as shown by the following table:

FUEL ISSUED DURING THE MONTH OF DECEMBER, 1909, FOR THE OIL-BURNING ENGINES OF THE ATCHISON, TOPEKA & SANTA FE R. R.

Points of Issue.	Oil in Barrels.
Albuquerque	978
Gallup	4,294
Winslow	20,925
Pinta	39
Flagstaff	732
Williams	11,373
Ash Fork	9,157
Seligman	18,402
Corcoran	1,010
Merced	286
Fresno	17,973
Stockton	8,926
Richmond	16,933
Riverbank	3,609
Glen Frazier	2,190
China Basin	1,533
Victorville	42
San Bernardino	35,503
Los Angeles	24,628
Santa Ann	1,250
Oceanside	4,050
National City	2,643
Olinda	322
Perris	138
Redondo	288
Total	313,988

A very careful accounting is kept by the fuel department, under charge of the general storekeeper, of all the oil issued to the engines. There are in the different offices calibration sheets showing the capacity of all oil tanks for different heights in inches. When oil is issued to any engine record is made of the depth of the oil in the tank before and after the oil is issued. Computation is made as to the number of pounds of oil issued, and the oil issued is charged to the engines in question. The amount of oil used in the round-house is determined by making further measurement of the quantity of oil in the tank at the time the engine leaves the round-house. Credit is given to the engineer for the amount of oil issued in firing up the engine, the same being charged to round-house account. At the end of each month the fuel department issues statements showing the total engine-miles, total ton-miles, pounds of oil consumed, average pounds of oil per hundred ton-miles, and the average tons hauled by trains for each engine on the different districts throughout the system. An average is then established of the number of pounds of oil per hundred ton-miles and a balance is struck in dollars and cents to show the gain and loss by each engine, depending upon whether its individual performance was smaller or greater than the average performance of all engines on its territory.

All data on fuel consumption are given a careful and critical study by the road foremen of engines, master mechanics, mechanical superintendents, fuel supervisors, and all others interested in the fuel performance of engines.

RAILWAY FUEL SUPPLY

By Raffe Emerson

"THIS 'ERE PROGRESS, IT KEEPS ON . . ."

ONE quarter of the coal mined on the North American continent is used by its railways, the 60,000 locomotives in the United States alone taking over one hundred millions tons each year at a rising price (1909, about $2.00 per short ton).

This expense for locomotive fuel is practically a tax of one cent a day on every man, woman and child in the country. Any means for reducing this growing cost, in however small degree, are worthy of the interest, attention and consideration of all the people as citizens, as well as of statesmen, financiers, economists, railroad men and engineers.

Five per cent. of this huge fuel bill (that literally consumes nearly the hundredth part of the people's wealth every year) is a charge against it that does not add in any material way to the fuel value of the coal burned, but rather the reverse, namely, the cost of loading this fuel onto locomotive tenders out of cars from the mines. This expense averages fully twice what it demonstratedly should be (could be, and in places *is*), and its reduction, through the use of efficient modern types of fueling stations, would bring about as correlative benefits a great decrease in the amount of human labour now spent in the dirtiest, most back-breaking toil, and would also eliminate much crumbling and deterioration of the coal from unnecessary handling.

Impressed with this aspect of practical conservation of fuel resources (and it may be added, of human energies), the International Railway Fuel Association at its yearly meeting last summer discussed an important committee paper upon the following subject:

STANDARD TYPE OR TYPES OF COALING STATIONS; BEST DESIGN AND MOST ECONOMICAL COAL CHUTE FOR HANDLING COAL FROM CARS TO LOCOMOTIVES.

Of course, the committee did not solve, for all time to come, the question set before it—nor as a matter of fact in its own mind even for the time being. It soon perceived that the question would not be "solved" probably as long as steam locomotives hauled land traffic; obviously, too, it could not favour or deprecate existing appliances (patented and put up by engineering contractors of widest repute) in use upon railways whose responsible officials were members of the association. But notwithstanding the delicate ground and the general invidiousness of comparisons, the work of the committee was exceedingly well done, and the tabulation it secured of a year's record of operation of the principal types of coaling stations on some of the main railways was fairly representative of better practice and covered over three per cent. of all the railway fuel handled in the United States. This tabulation (reduced to cost-per-ton basis) is reproduced below.

One of the interesting facts shown in this table is the depreciation and interest charge (taken at a low average figure for structures and apparatus of this kind of one per cent. per month) amounting to nearly one-third of the cost of handling. Moreover, the stations representing the most liberal investment per ton handled not always showed the least la-

bour cost—rather almost the reverse.

These figures, while valuable and instructive, are not wholly to be depended upon, as they represent in some instances selected cases; as they are not summarized from accounts mutually including and excluding all the same elements, and are therefore not wholly comparable; and as some of the most important, though indirect, aspects of the whole problem (amounting to far more in cost than the entire expense of handling alone) are left out of the reckoning altogether. The committee realized that: "Cost, in its various phases and as a whole, is the determinant as to fueling station type. Uniform detail accounting of all elements of handling cost is necessary for reliable comparison and study"; and that "the Association should recommend a uniform blank for this purpose as the first step toward recommending standard fueling station practice." The association therefore placed the preparation of such a blank in the hands of a

Number of Chutes.	Type of Chutes and Location, etc.	Costs in Cents per Ton Handled. Cost of Installation per Ton Handled Daily.	Interest and Depreciation on Plant at 1% per Month.	Maintenance.	Supplies.	Labor.	Total.	Yearly Tons Handled.
Type one, 25 chutes	Shoveling chutes, inclined trestle, served by locomotives; chutes located in Mo., Texas, Ala., Miss., Minn., Ia., Kan., Okla., Ark., Ind., Ky., Tenn., on Lines of M. K. & T., 'Frisco, Rock Island, C. & E. I., Penna. R. R., and Queen and Crescent system	$70	2.3	0.2	0.	8.4	11.1	710,735
Type two, 14 chutes	Gravity chutes, timber construction, using self-clearing cars. Served by locomotives and gasoline or electric cable hoist. Chutes located in Kan., Texas, Okla., Mo., Miss., Ala., Ark., Ill., Ia., on lines of M. K. & T., Rock Island, 'Frisco, and C. & E. I. R. R.	90	3.0	0.4	0.3	2.9	6.5	610,041
Type three, 9 chutes	Holman type. Using one to four balanced buckets with capacity of one to three tons each. Chutes located in Ill., Ia., Mo., Ark., Okla., and Pa., on M. K. & T., 'Frisco, Rock Island, Penna. R. R., and C. & E. I. R. R.	71	2.3	0.5	0.	2.8	5.8	471,103
Type four, 8 chutes	Trestle platform. One ton or more capacity buggies. Gondola and covered cars placed by locomotives. Chutes located in Ky., Tenn. and Ala., on Queen and Crescent System	113	3.8	0.2	0.1	7.3	11.4	296,232
Type five, 6 chutes	Air hoist. Crane and buckets. Air pressure furnished by locomotive taking coal. Located in Texas, Kan., Ia., Minn. and Ind., on lines of Penna. R. R., M. K. & T., and Rock Island	50	1.7	0.7	0.	15.6	18.2	33,505
Type six, 7 chutes	Bucket conveyor type. Using gasoline, steam and electric power. Self-clearing cars employed. Located in Ia., Kan., Ind., Mo., Ohio and Tenn., on lines of M. K. & T., Penna. R. R. and Rock Island	60	2.0	0.7	0.5	2.5	5.7	698,988
Type seven, 3 chutes	Inclined conveyor. Rubber or canvas belt. Gasoline, electric and steam power. Self-clearing cars used. Located in Ill. and Pa., on lines of Rock Island, C. & E. I. and Penna. R. R.	91	3.0	0.7	0.4	4.1	7.5	267,226
Type eight, 4 stations	Locomotive crane and clam-shell. Gondola cars used. Located in Ill., Mo., Okla. and Tenn., on lines of 'Frisco, and Queen and Crescent System	44	1.5	0.2	0.8	4.0	6.4	250,992
Total, 76 sta.	Eight types	$75	2.5	0.4	0.3	4.7	7.8	3,338,822

committee for the ensuing year, the writer being a member of this committee.

The load fuel on locomotives costs roughly 8 cents a ton, the average being more nearly 10 cents. In actual instances it may get under 4 or 5 cents, and I firmly believe that a figure between 1 and 2 cents is not chimerical to hope for, nor an average figure of 3 cents a ton, covering all direct costs including interest and depreciation, a reasonable expectation for the developments of the next years.

The present average charge is about as follows:

	Cents per Ton to be Handled.
Interest and depreciation	3.0
Maintenance	1.0
Labor	6.0
Supplies	0.0
	10.0

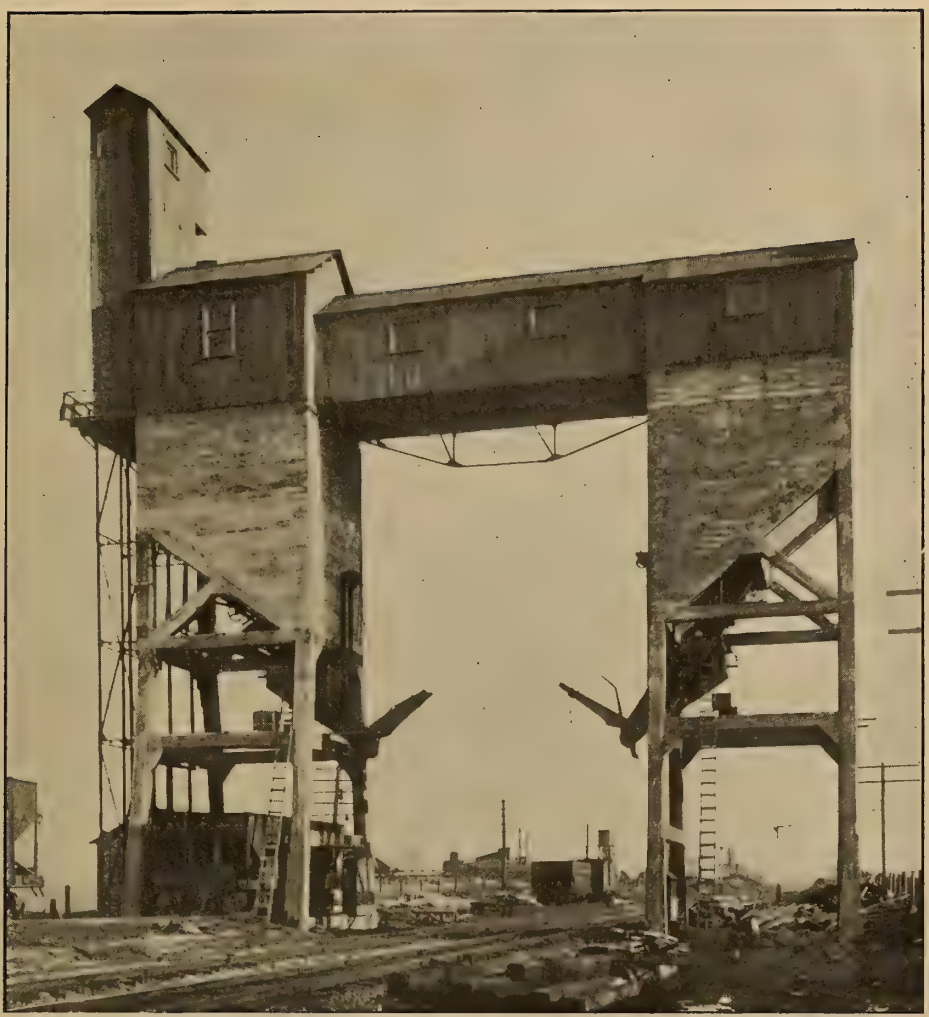
Discussing these items in turn, we find that the interest and depreciation depend principally on the capacity of the fueling station in tons handled per day, for a given investment, and secondarily upon the durability of the structure and apparatus. The following table shows the interest and depreciation, figured at three in fueling plants per ton capacity per day. This table makes it very easy to determine the amount to add to the cost of handling fuel in order to arrive at the full cost per ton including interest and depreciation at a given rate. The investment cost of the fueling station is divided by the average daily tonnage issued to locomotives, giving "investment per ton capacity," and the intersection of this line, with the selected "Interest and Depreciation" column, gives the cost per ton of the latter.

TABLE OF INTEREST AND DEPRECIATION COSTS PER TON HANDLED BY LOCOMOTIVE FUELING STATIONS, FOR A GIVEN INVESTMENT PER TON DAILY CAPACITY, AND FOR A GIVEN RATE OF INTEREST AND DEPRECIATION.

Investment per Ton Daily Capacity, Dollars.	Interest and Depreciation in Cents per Ton Loaded on Locomotive at a Rate Yearly of		
	8 Per Cent.	12 Per Cent.	20 Per Cent.
5	.1	.2	.3
10	.2	.3	.6
20	.4	.7	1.1
30	.7	1.0	**1.7**
40	.9	1.3	2.2
50	1.1	1.7	2.8
60	1.3	2.0	3.3
70	1.6	**2.3**	3.9
80	1.8	2.6	4.4
90	2.0	3.0	5.0
100	2.2	3.3	5.6
120	**2.7**	4.0	6.7
150	3.5	5.0	8.3
200	4.4	6.7	11.1

The figures between the heavy lines indicate usual ranges, and the heavy-face figures what may be con-

FAIRBANKS-MORSE STATION SERVING THREE TRACKS. CAPACITY 400 TONS



CONCRETE-STEEL FUEL STATION FOR SOUTHERN RAILWAY AT ASHEVILLE, N. C. CAPACITY 1,000 TONS. BUILT BY ROBERTS & SCHAFER, CHICAGO, ILL.

sidered good standard practice. From this table a very simple rule governing fuel station investment, or investment in fueling station improvements, may be adduced:

Find the cost per ton of the interest and depreciation charge on the proposed investment and see whether it is substantially less than the saving in handling cost effectably by making the investment.

The durability of the station and accessories also affects the maintenance charge to a large degree. In this charge probably the "fire risk" should be properly included. In a modern station the maintenance should be low—less than 1 cent per ton handled, ¼ cent being an entirely practical and attainable figure.

	Cost per Ton in Cents.		
	Minimum.	Average.	Maximum.
Unloading from car.....	0.03	2	10
Operating fuel station...	0.1	1	5
Loading on engine.....	0.2	3	15
Total.....	0.3	6	30

Labour may be subdivided into

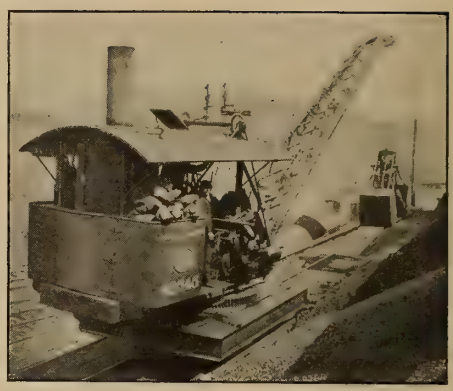
elementary operations (sometimes combined, or still further subdivided) as indicated by the preceding table.

An automatic balanced bucket type of fueling station, served by the very best self-clearing coal cars, handling 250 tons in twenty-four hours, and using the services of one man but half a day, coal being taken by gravity by the locomotive firemen, would give the minimum cost above indicated.

Supplies are a considerable item only in mechanical or power crane or hoist-drum types or station. This charge will run from practically nothing to 1 or 2 cents per ton, according to fuel or power used. Properly to be considered in this item, although not so charged in the Inter-State Commerce Commission's Official Classification of Railroad Accounts, is the cost of switching service, placing cars on trestles, setting them, withdrawing empties, etc. This service is worth about $2.00 per hour, and as an average yard locomotive will handle from two to twenty cars per hour, in or out (average about six, allowing for locomotive in service day and night), the cost per ton will be about ½ cent to about 5 cents, and an average about 2 cents per ton.

Three mighty important aspects of this problem, amounting to a much greater money value than the entire

SMALL LOCOMOTIVE CRANE FOR ASHES AND COAL. BROWNING ENGINEERING CO., CLEVELAND, OHIO



LOCOMOTIVE CRANE WITH NEW STYLE BUCKET IN OPERATION. INDUSTRIAL WORKS, BAY CITY, MICH.

cost of handling the fuel, direct and indirect, are usually but little considered, because railway accounts are kept to show money expenditure rather than time expenditure, notwithstanding that in transportation, in the use of equipment—cars, locomotives—for handling a volume of traffic, *time is money*. These three aspects are:

Detention of locomotives for coaling;

Detention of coal cars for unloading;

Transportation cost of company's supply fuel in cars over company's own lines (such freight charges being over foreign or other lines about one-half of the average $2.00 per ton cost of railway fuel).

A fourth item of great importance, which may equal or perhaps exceed the handling charge, is the deterioration and crumbling of the coal, due to the way it is handled and re-handled.

These four large items of correlative cost, affected by the way the fuel is handled at the fueling station, range about as follows (locomotives are worth in earning power from about twenty to *several hundred* dollars per day; an average tenderload of coal will be from 4 to 15 tons, say about 7.

(Cars earn from $1.00 to about $10.00 per day, average being about $3.00.)

Locomotive Detention in Minutes.		Value of Locomotive Time, in Earning Power, per Detention per Ton of Coal Loaded. Values in Cents.		
		Minimum.	Average.	Maximum.
Minimum:	1.....	0.1	0.8	5.0+
Average:	12.....	1.0	9.0	50.0+
Maximum:	6 hours....	25.0	$3.00	$30.00+

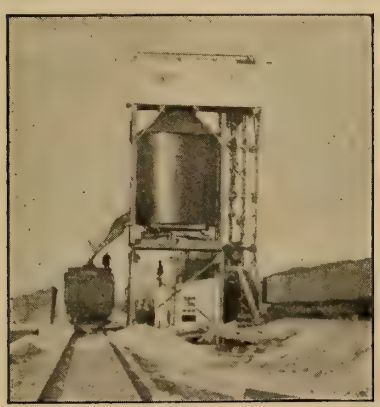
Car Detention for Unloading.		Value of Time in Cents per Day Detention per Ton of Coal Unloaded.		
		Minimum.	Average.	Maximum.
Minimum:	10 min. +..	....	0.5	0.25
Average:	8 days.....	16.0	60.0	$3.00
Maximum:	20 days +..	40.0	$1.50	$10.00

Costs of transportation will vary from less than 0.1 cent per commodity ton mile to over 3 cents, and average about 0.3 cent. Taking the average figure, the following table gives the cost of hauling railway fuel per ton of fuel for distances one mile to one thousand miles:

AVERAGE COST OF HAULING ONE TON OF COAL, IN DOLLARS.

Miles.	Cost.	Miles.	Cost.	Miles.	Cost.
1.....	$0.003	10.....	$0.03	100.....	$0.30
2.....	.006	20.....	.06	200.....	.60
3.....	.009	30.....	.09	300.....	.90
4.....	.012	40.....	.12	400.....	1.20
5.....	.015	50.....	.15	500.....	1.50
6.....	.018	60.....	.18	600.....	1.80
7.....	.021	70.....	.21	700.....	2.10
8.....	.024	80.....	.24	800.....	2.40
9.....	.027	90.....	.27	900.....	2.70
10.....	.030	100.....	.30	1000.....	3.00

The relation of fuel value to economical transportation zone has been elaborately developed in a thoroughly practical way by Mr. Crawford, of the Chicago, Burlington & Quincy Railroad, and those interested are referred to his paper before the Western Railway Club of Chicago.

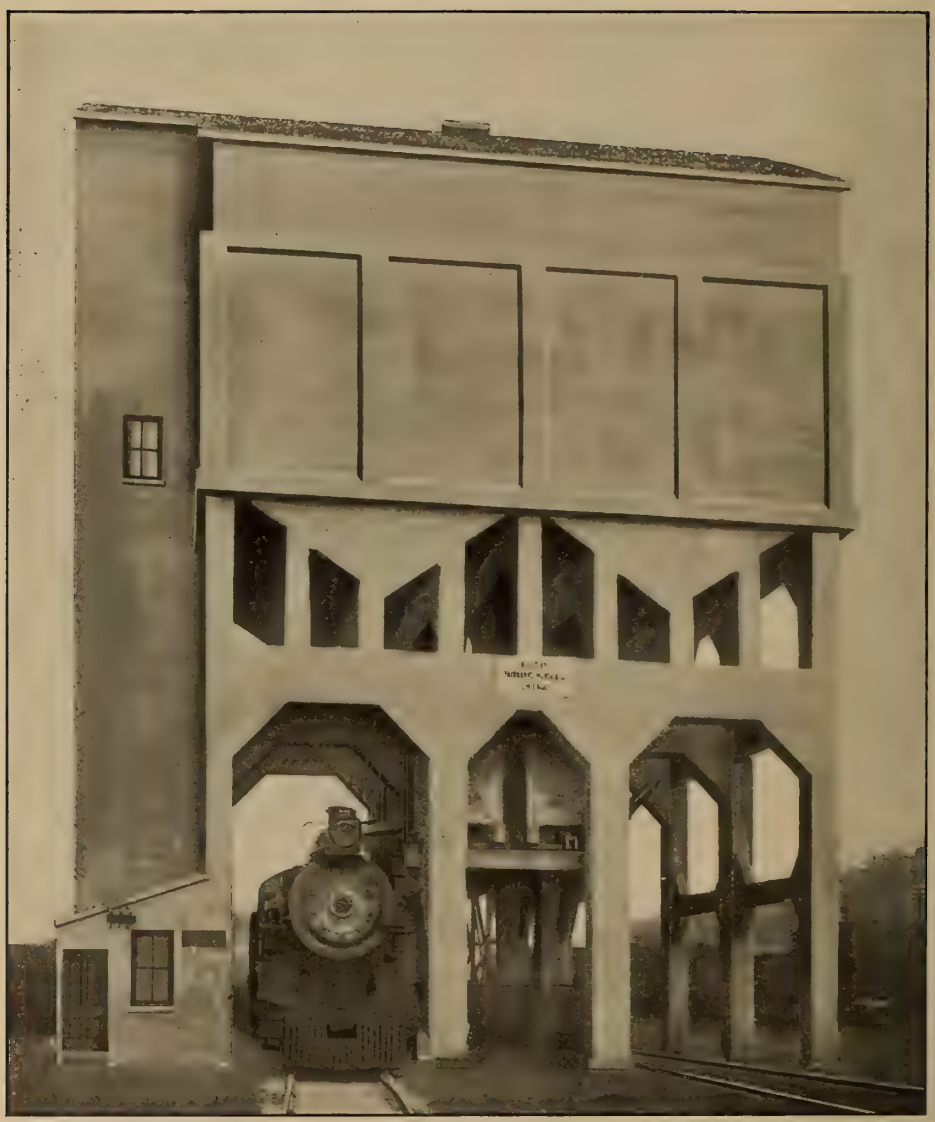


STEEL FUEL STATION ON THE UNION PACIFIC RAILROAD

POWERFUL BUCKET FOR PICKING UP CLINKERS AND FROZEN COAL. INDUSTRIAL IRON WORKS, BAY CITY, MICH.

"Run-of-mine" coal is generally bought for locomotive use, both because it is cheaper per ton and because its purchase helps the mine operator to dispose of an otherwise often unmarketable product (this policy being a practical conservation measure). "Run-of-mine" will "run" 25 to 60 per cent. of black, the average being over 35 per cent. "Run-of-mine" is priced from 10 to 30 cents per ton less than screened coal. Each per cent. of slack is therefore worth a price difference of about ½ cent. Every handling of the coal will result in a breakage or crumbling of one to three per cent., and will run as high as 8 per cent. with some types of mechanical plants. As each ton of coal is handled from one to three or more times from car to tender, averaging twice, the deterioration in value due to crumbling amounts to from ½ cent to 4 or 5 cents a ton, averaging between 1 and 2 cents.

The reduction in steaming capacity will be about half of the cinder per-



CONCRETE-STEEL FUEL STATION, SERVING FOUR TRACKS, CAPABLE OF SERVING EIGHT. BUILT BY ROBERTS & SCHAFER, CHICAGO, ILL.

centage—thus 10 per cent. cinders will reduce the locomotive efficiency by about 5 per cent compared with the use of a cinderless fuel. As the locomotive is worth from twenty to several hundred dollars per day earning capacity, the reduction of capacity due to cinders ranges in value from 50 cents to $40.00 or $50.00 per day. On a fuel consumption per locomotive of from 4 to 20 tons per day this loss in steaming or hauling efficiency is equivalent to from 10 cents to $4.00 per ton of coal fired averaging about 50 cents. Putting it another way, each per cent. added to the slack means a reduction in earning capacity of the locomotive about 2 cents per ton of coal fired, beside an average loss of unburned fuel itself of another cent per ton per 1 per cent. of slack.

To restate: Each handling of the coal causes an addition to the slack of about 2 per cent., which results in fuel and efficiency losses of about 55 cents per ton. These losses are as low as 12 cents and as high as $4.00 per ton handled. These figures are given at considerable length to demonstrate the great desirability of designing coal-handling appliances, so that the coal will suffer the least possible crumbling.

The controlling factors in handling fuel on railways have been stated and developed, and may now be summarized:

Fuel for locomotive supply costs at the mine 75 cents to over $3.00 per ton, averaging but slightly over $1.00.

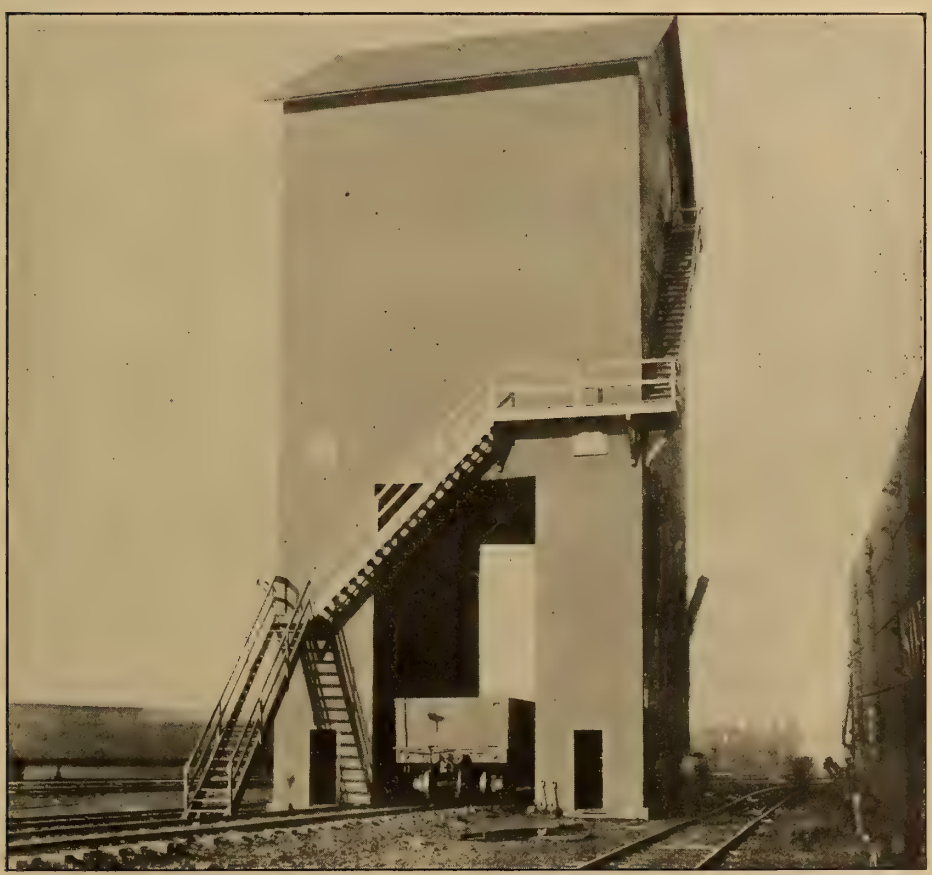
Freight charges over *other* ("foreign") lines range from nothing to about $3.00, and average slightly under $1.00 per ton.

Cost of transportation over company's own lines ranges from nothing to about $5.00 per ton, averaging roughly 40 cents.

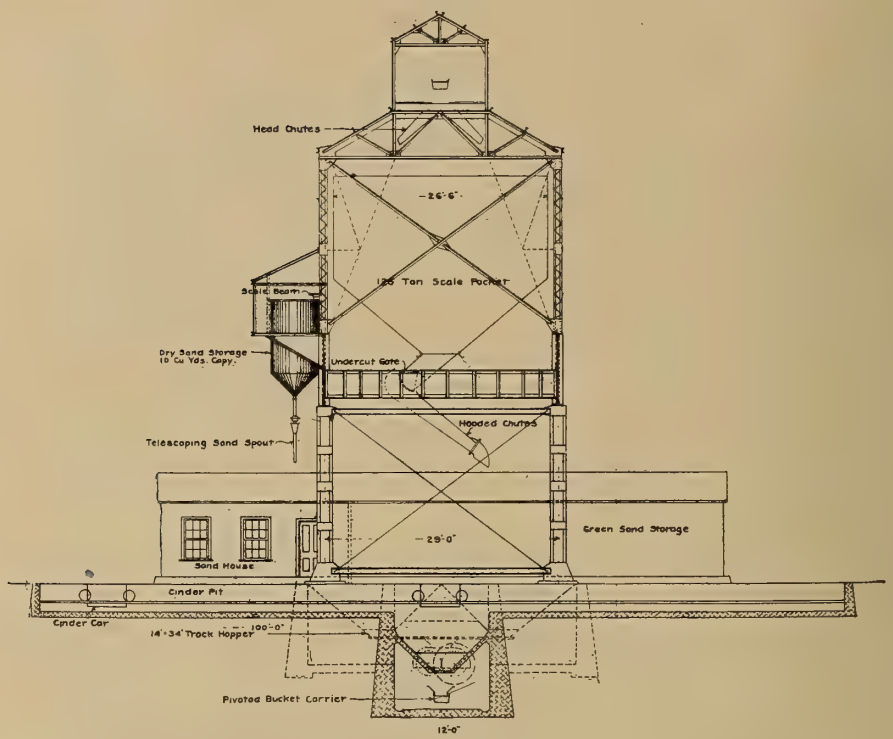
Time on cars at mines and in transit is valued at from a minimum of about 3 cents per ton to over $5.00, averaging some 60 cents.

Empty car movement entails a further transportation cost of 35 cents a ton average, ranging up to $3.00.

Car detention at fueling station



FUEL STATION BUILT BY FAIRBANKS-MORSE AT LOUISVILLE, KY. CAPACITY 535 TONS, AND PROTECTED FROM LOCOMOTIVE SPARKS BY CORRUGATED IRON SIDING



LONGITUDINAL SECTION OF STANDARD COAL, CINDER AND SAND STATION OF THE UNION PACIFIC RAILROAD. CAPACITY 500 TONS

ranges from practically nothing to $10.00 per ton, averaging 60 cents.

Switching service at the fuel station costs from ½ cent to 5 cents per ton, the average being 2 cents.

Labour handling fuel at fueling stations ranges from 0.3 to 30 cents per ton, averaging 6 cents.

Power and supplies for fueling station, from nothing to 3 cents per ton, averaging about 0.2 cents.

Maintenance of fueling station, from 0.1 to 2.0 cents per ton, averaging a little over 1 cent.

Interest and depreciation on fueling station, from 0.4 to about 6 cents per ton, averaging about 3 cents.

Taxes, ground rent, supervision and other general charges, from 0.1 to about 0.3, average about 0.1.

Detention of locomotives being coaled, 0.1 cents per ton coaled, to $30.00, average about 9 cents.

Loss of fuel value and locomotive efficiency from crumbling due to

SUMMARY OF LOCOMOTIVE FUEL COSTS PER TON.

Order of Importance.	Item.	Average Per Cent. of Cost.	Minimum, Cents.	Average, Dollars.	Maximum, Dollars.
2	Price at mine	24	75	$1.10	$3.00
3	Freight	19	0	.90	3.00
5	Transportation	9	0	.40	5.00
1	Use of transportation	32	4	1.50	18.00
8	Switching	0	0	.02	.05
7	Total fuel station	2	1	.10	.35
6	Locomotive detention	2	0	.09	30.00
4	Unnecessary slack	12	12	.55	4.00
	Total	100%	92c.	$4.66	$63.40

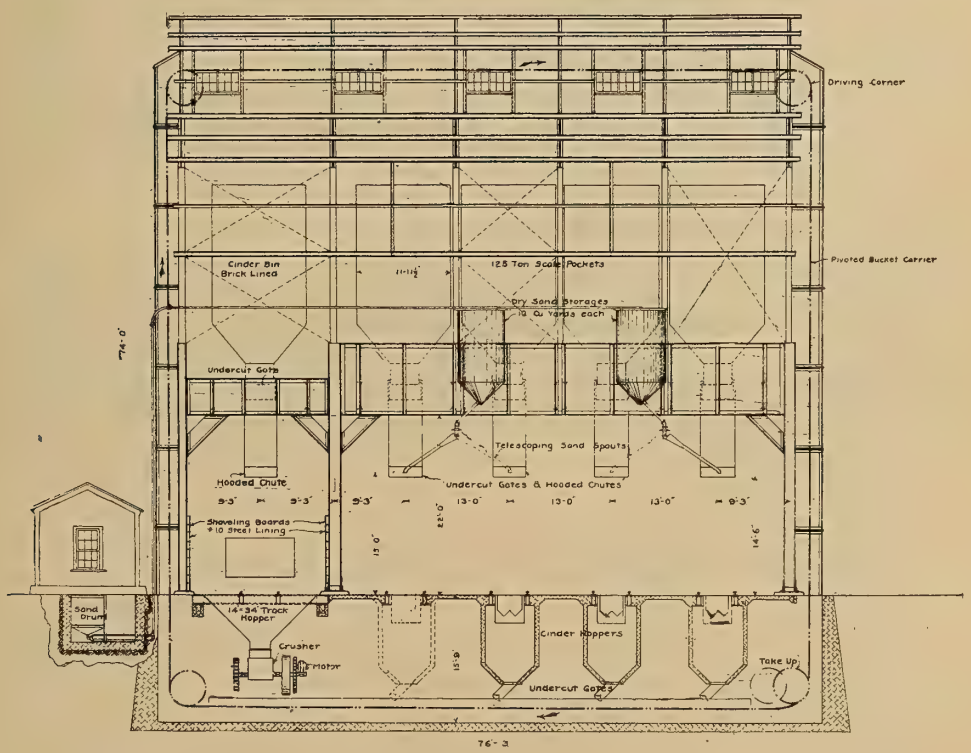
handling, from 12 cents to $4.00, average over 50 cents.

By the above table it is seen that the most important consideration in railway fuel supply is the location of the source of the supply, with reference to the principal fueling stations where the supply is delivered to locomotives, and the efficient movement that is given to its transit.

The next consideration is price, relative to quantity (i. e., per cent. of slack and sulphur). The last consideration is fuel station operating efficiency, including promptness of loading engines; indeed this last factor may overshadow all others in money value, becoming ten times all other costs, including purchase price of fuel put together. Under circumstances where engine time is of great value (almost invariably the case where the engines are assigned to a "pool" or to "rounds"), the presence of a coaling station of the most modern type, coaling the engine with the greatest expedition and with the least injury of the fuel, becomes a transportation necessity.

The main features controlling design are:

1. Daily capacity required.
2. Is ground storage feasible or desired?
3. Terminal station or isolated plant.
4. Location.
5. Kind of car used.
6. Release of cars.
7. Switching.
8. Number of tracks served and clearances.
9. Kind of construction and fire risk and protection.
10. Installation or desirability of weighing or measuring apparatus.
11. Combination fueling operation with ashing, watering and sanding,



CROSS SECTION OF STANDARD UNION PACIFIC STATION

in one station, and with one engine movement.

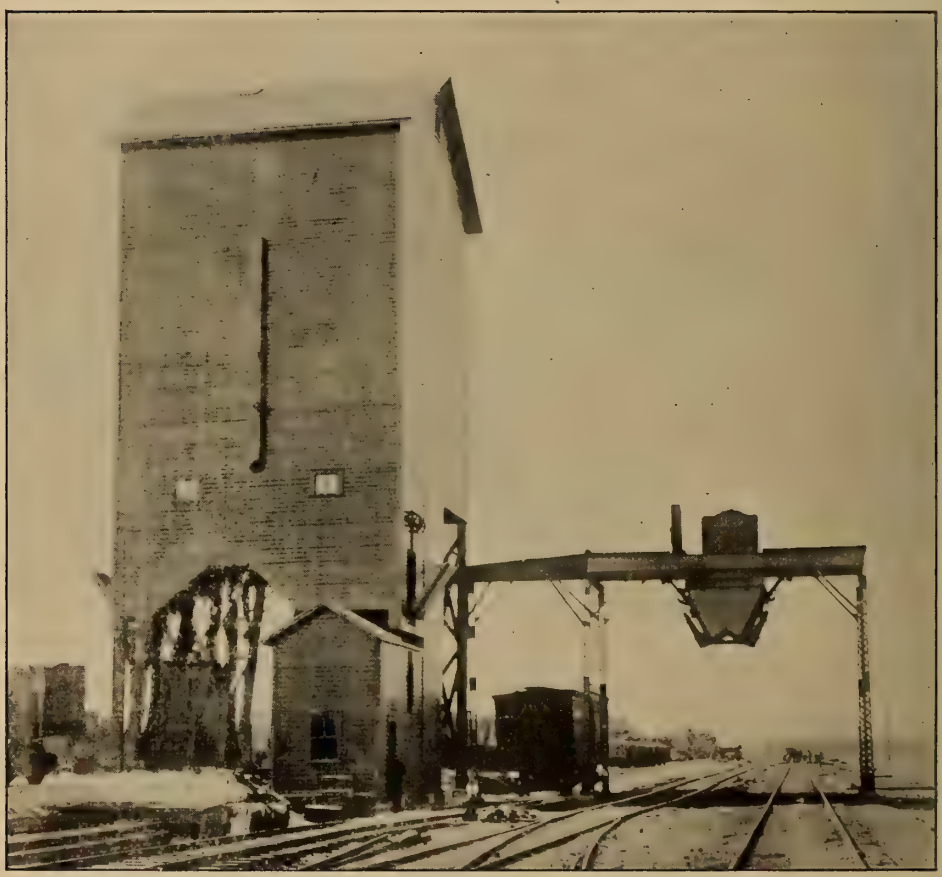
12. Kinds of fuel used, whether mixed, and preparation required.

13. Power available.

The variations in detail of design, the different combinations of elements of design, are so many and so varied, that no description or classification of the existing types will be attempted here. The illustrations give sufficient example of that variety in its better combinations. But the underlying elements of railway fueling stations may be outlined; such a station consists of:

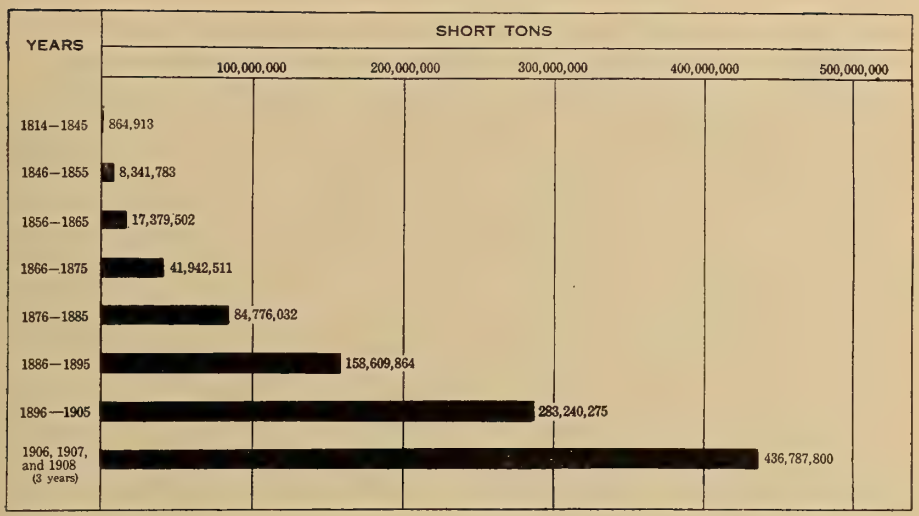
A track or tracks (siding) for (a) reception of cars of coal; (b) holding of cars of coal; (c) unloading of cars of coal.

Cars with supply of coal; reservoir for coal storage (ground or bin); main and auxiliary; track or tracks for engine supply; intermediary to supply coal to engines from reservoir (or from cars). All fueling stations combine these elements in varying degree.



FAIRBANKS-MORSE 300-TON STATION WEIGHING ENGINE LOADS ACCURATELY AND QUICKLY.
This station has reduced the fuel bill of the Atchison, Topeka & Santa Fe Railroad $1,000,000 a year.

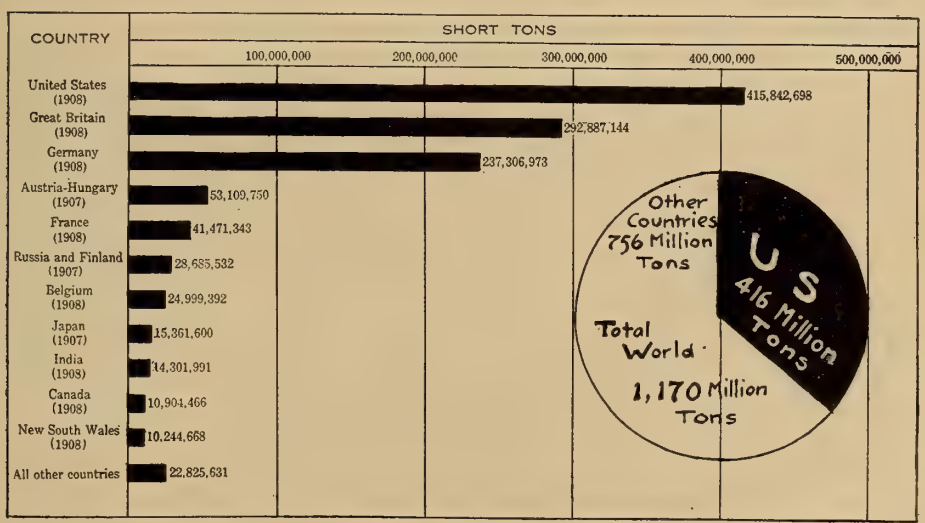
In conclusion it may be repeated that the several items, both direct and indirect, affecting locomotive fuel cost aggregate about $5.00 per ton, or about five times as much as the price of the fuel at the mine, although an attainable minimum of $1.00 per ton is indicated. The type



AVERAGE YEARLY PRODUCTION OF COAL FOR EACH DECADE IN THE UNITED STATES SINCE 1814

and operation of the fueling station may affect this cost (indirectly rather than directly, as in saving locomotive time in coaling, or handling coal without crumbling) in very marked degree, and is worthy of the most serious study and attention. But little of definite value in the way of information upon which to base conclusions and make decisions can be secured without adequate records, complete as to detail, comprehensive as to interaction of all the various factors to be considered.

The installation of complete *records* of all the items of fuel cost here considered will yield far more instructive and valuable results in the reduction of railway fuel expense than an equal amount of money spent in any other way. The return is actually over 100 to 1.



THE WORLD'S PRODUCTION OF COAL DURING 1908

THE EQUIPMENT OF RAILWAY WORKSHOPS

CURRENT BRITISH PRACTICE

By G. H. Burrows, A. M. Inst. M. E.

THE growth of rolling stock of railways has necessitated the expansion and reconstruction of existing shops, or the transference of works bodily to other sites and the equipment of the shops on modern lines. As an instance of the latter, there is the transference of the locomotive shops of the London & South Western Railway from Nine Elms to Eastleigh. In cases where the foresight of early railway managers placed the shops for construction and repairs in a district where it has been possible to acquire fresh land, it has followed that depots have been extended, in the way of reconstructing existing shops, or preferably building new.

In the modern shop, be it for forge, foundry, boilermaking, erecting, sawmill, stamping or painting, more generous consideration is shown for light, space, and more convenience for its special purpose than in the early railway shops of our forefathers; and present-day methods of power distribution, in the form of electric, hydraulic or pneumatic, have necessitated a thorough reconsideration of design. High-speed tool steel in quite recent years has also contributed its quota, and that not a small one, to an alteration of method and equipment.

The development of the gas producer has made it possible for central power stations to be self-contained where it is not convenient to purchase power in the form of electric energy from an outside source and to obtain gas from a main gas works. The illustration and line diagram, Figs. 1 and 2, show a recently erected power station fitted with suction gas producers, with space to erect for future developments. The plant consists of two 250 brake-horse-power, vertical, four-cylinder gas engines, coupled direct to dynamos capable of generating 150 kilowatts each at a tension of 250 volts. Two gas producers are at present provided, each set comprising a generator, double scrubber, gas box, etc. The charging floor is level with the top of the producers. Fuel is supplied from a coal bunker of ample capacity outside the building, which is fed by hopper wagons from an elevated road. For facility in lifting, for repairs or renewals, overhead cranes of 6 tons capacity are provided in both engine and generator houses, driven by hand ropes from the floor.

It is usually convenient for the hydraulic power and air-compressing plant to be arranged in one power house. The hydraulic accumulators, of which two are required, loaded to 800 and 1,500 pounds per square inch, respectively, should be fed by pumps of ample capacity, to provide against sudden calls of power by the presses, lifts and tools in the shops supplied. The lower pressure is sufficient for hydraulic riveters, small presses, lifts, etc., whilst the higher pressure is necessary for the large flanging presses in the boiler shop and forge. Where it is necessary, this latter pressure is increased locally by an intensifier or by separate pumps at the machine itself to the required pressure of 2,000 or more pounds per square inch.

Air compressors are provided in duplicate or triplicate, one acting as

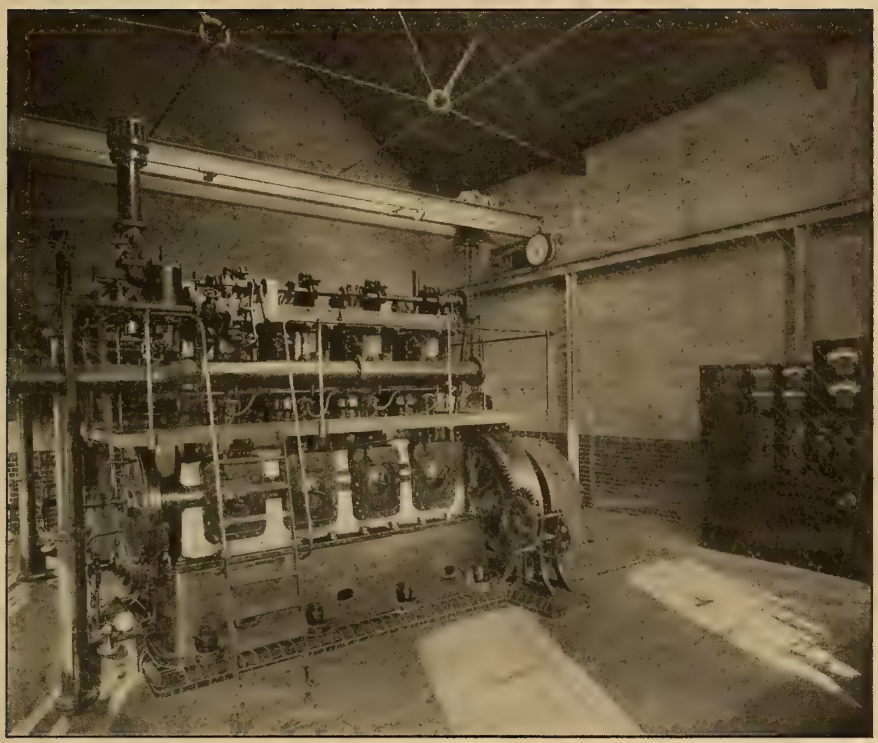


FIG. 1.—GAS POWER STATION FOR RAILWAY SHOPS

a stand-by in case of failure. The Ingersoll-Sergeant type of steam-driven compressor provides a useful arrangement for the purpose of air supply for pneumatic tools. The pressure usually adopted is 80 pounds per square inch, and the two-stage compressor with an intercooler will reduce the loss of work due to heating to about 14 or 15 per cent. Maintaining reservoirs and distributing mains convey the air to the respective shops, and supply pipes with hose connections make it possible to use a pneumatic tool wherever required.

From the consideration of the provision of power in its different forms arises the question of the best means of its transference to the shops requiring it. When hydraulic, compressed air, water, gas, or surface water pipes are laid in the ground they become a source of continual anxiety to the works manager. Leakages from compressed air and gas mains are difficult, if not well-nigh impossible, to detect at times, and from hydraulic or water pipes they become obvious where least expected or desired. The line diagram (Fig. 3) shows a section through a pipe subway of ample proportions to give facilities for examination of the different pipes and mains running through a large factory. As will be seen, the subway is cylindrical in form, 7 feet internal diameter, and formed of three rings of brickwork 14 inches thick. The floor is 1 foot above the invert which is formed to carry off clean waste water. The section brackets are built in to carry the pipes, three of which are for gas, one for water, one for compressed air, one trough for electric cables, and two hydraulic mains. The greatest depth of invert is about 17 feet from the ground, and small ventilator shafts are provided where

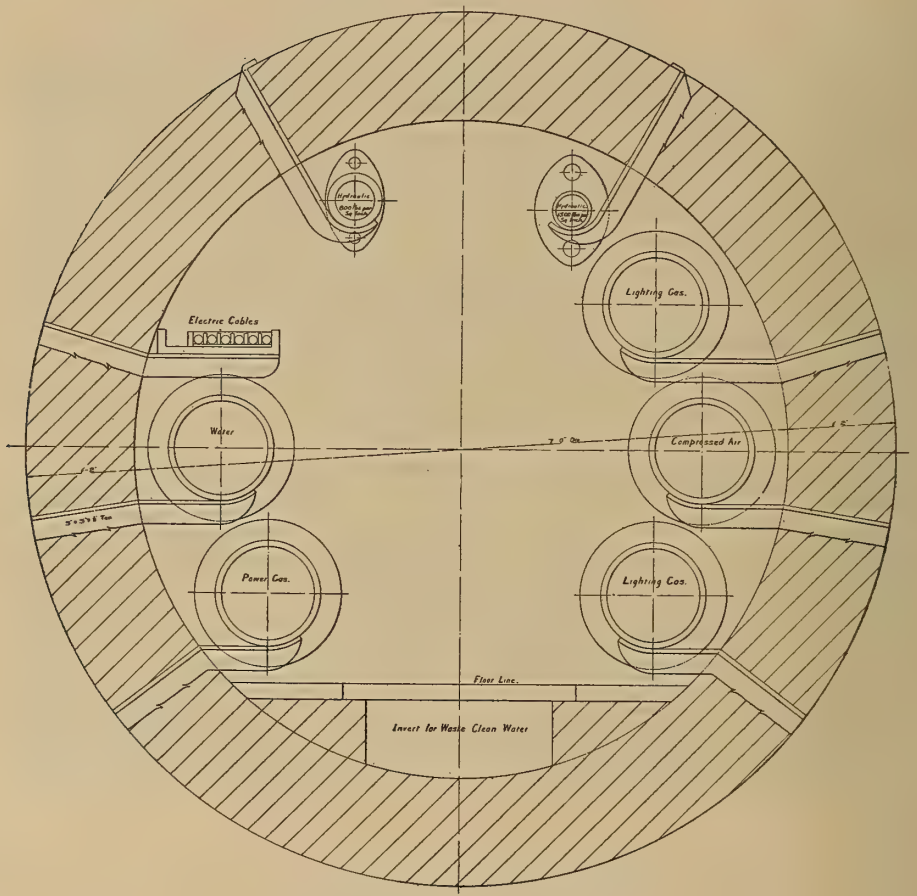


FIG. 3.—PIPE SUBWAY FOR SHOP SERVICE

convenient. It may be objected that this method is costly, but when once laid it has been found to well repay the original outlay.

At the present day the boiler shop ranks among the first in order of importance. In addition to the possession of the necessary machine tools, the general efficiency of the shop demands careful attention to a convenient layout of machinery and floor space to obviate the handling and lifting of material more than once for practically each stage of the manufacture, from the receipt of the plates or raw material to the turn out of the finished boiler. A convenient arrangement places the hydraulic presses and machines at one side of the shop, where, after passing through the various operations in proper sequence, the plates, forgings, etc., are passed across the shop to the boiler makers, assembled and riveted up, thence into the boiler mounter's hands for tubing and mounting. The illustration (Fig. 4) shows the corner of a boiler shop, with plate furnace, coal or gas-fired, 600-ton hydraulic press and hydraulic crane for dealing with flanged plates, such as steel-throat and back plates and smoke-box front plates. The press has three main rams, four vice-rams, two steadying rams for the table, and an internal central ram for small work. The pressure is 800 or 1,500 pounds per square inch, as desired.

In the foreground is seen a steel-throat plate, flanged under this press in one heat, for a locomotive boiler

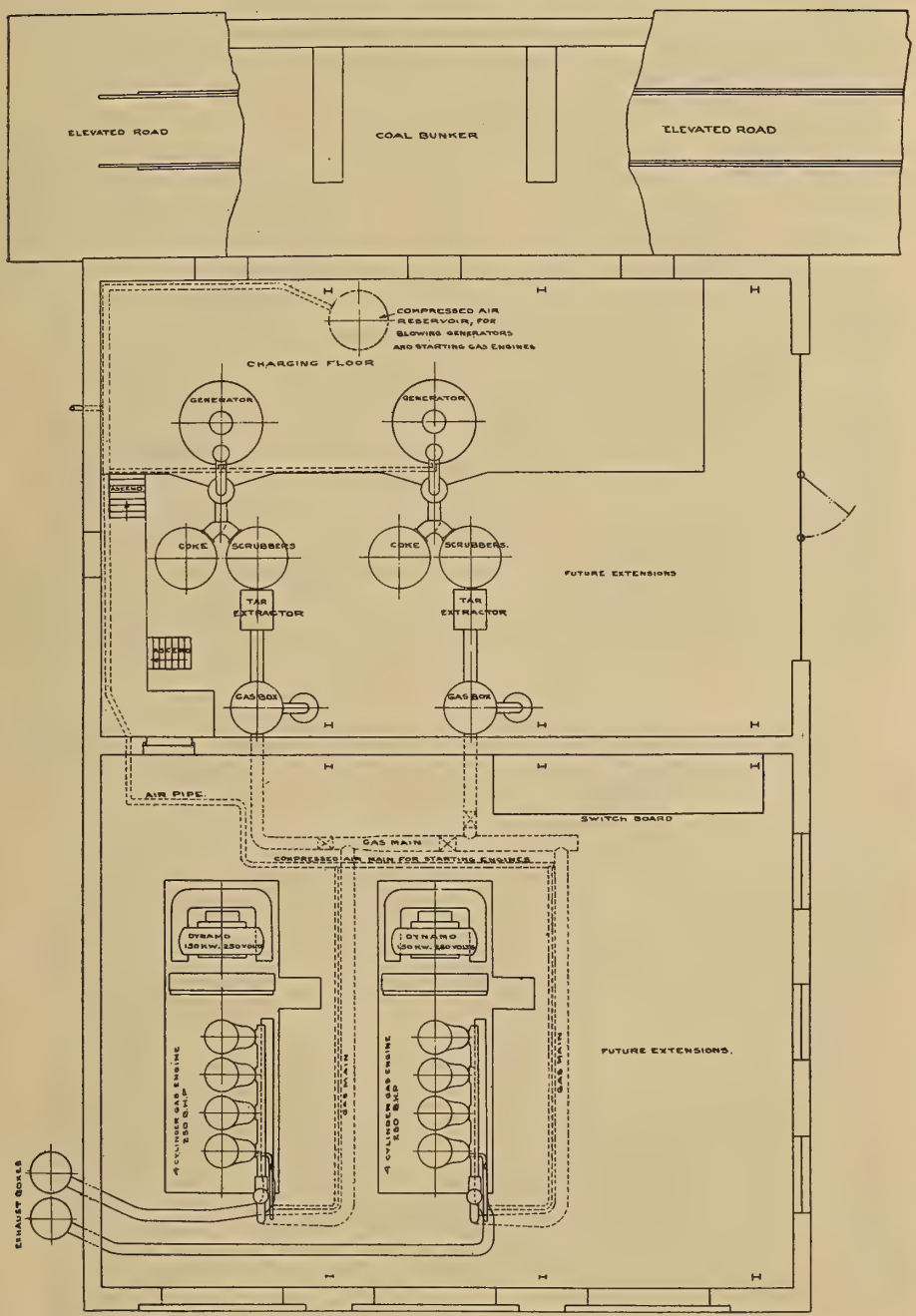


FIG. 2.—PLAN OF GAS POWER STATION

FIG. 4.—BOILER SHOP WITH HYDRAULIC PRESSES

FIG. 5.—A BAY IN THE BOILER SHOP

FIG. 6.—JIB CRANE AND HYDRAULIC RIVETER

of the Belpaire type. The actual plate shown has, since the operation, been marked off, rough edges cut, and drilled ready for riveting up. The width of the throat at the fire-box is practically the same as the diameter of the boiler, which at this point is 6 feet. The plate at the position of the arrow is flat and about 15 inches deep, and this, combined with the flat top of the crown which merges into the diameter of the boiler in the same depth, gives a good idea of the work done under a press of this description.

The crane is of 6 tons capacity, and at a pressure of 800 pounds per square inch slews, lifts and traverses simultaneously, and handles with ease the plates and heavy blocks and dies used at the press. Copper plates are generally flanged by hand on a former, but the fire-hole connection is produced by proper blocks under the flanging press. The uneven edges of the flanged plates, steel and cop-

FIG. 7.—VIEW OF FOUNDRY, WITH MOULDING MACHINES

per, are usually cut off by a horizontal band-saw. The work is fastened to a movable table with power feed, which can be varied to suit the material or class of work. The band-saw is carried on vertical pulleys, has a cutting speed of 260 feet per minute, and removes the metal at the rate of ½ inch per minute for steel and 2¼ inches per minute for copper plates.

Plates and forgings, such as foundation rings having a regular pitch of rivet hole, are preferably dealt with by vertical or horizontal multiple drilling machines, either in batches or singly, as the nature of the work permits.

Punching and shearing machines with gaps ranging from 36 to 24 inches are used for roughing out plates, which are afterwards planed or milled along the edges where necessary for caulking purposes.

Barrel plates are rolled to correct diameter in the ordinary three-roller plate-bending machine, and either before or after are drilled for riveting. In the former case the usual multiple drilling machine is employed; but the better method more often obtains of drilling after rolling on a specially designed machine for boiler barrels, which is seen in the illustration (Fig. 5) of one machine bay of a boiler shop. The machine, which is motor-driven, is suitable for other classes of work, and is shown with a Belpaire firebox 7 feet long in position for drilling. The table is circular, has a revolving motion, and traverse motion to and from the column which carries a balanced saddle with platform for the workman. The saddle is fitted with two drilling spindles, their position being variable horizontally and vertically and pointing towards the vertical centre line of the table. The latter can be canted from the horizontal, so as to deal with the taper sides of a firebox or coned barrel. The shop is provided with motor-driven 20-ton overhead-traveling cranes with a traveling speed of 6 miles per hour, and fitted with simultaneous traversing and lift-

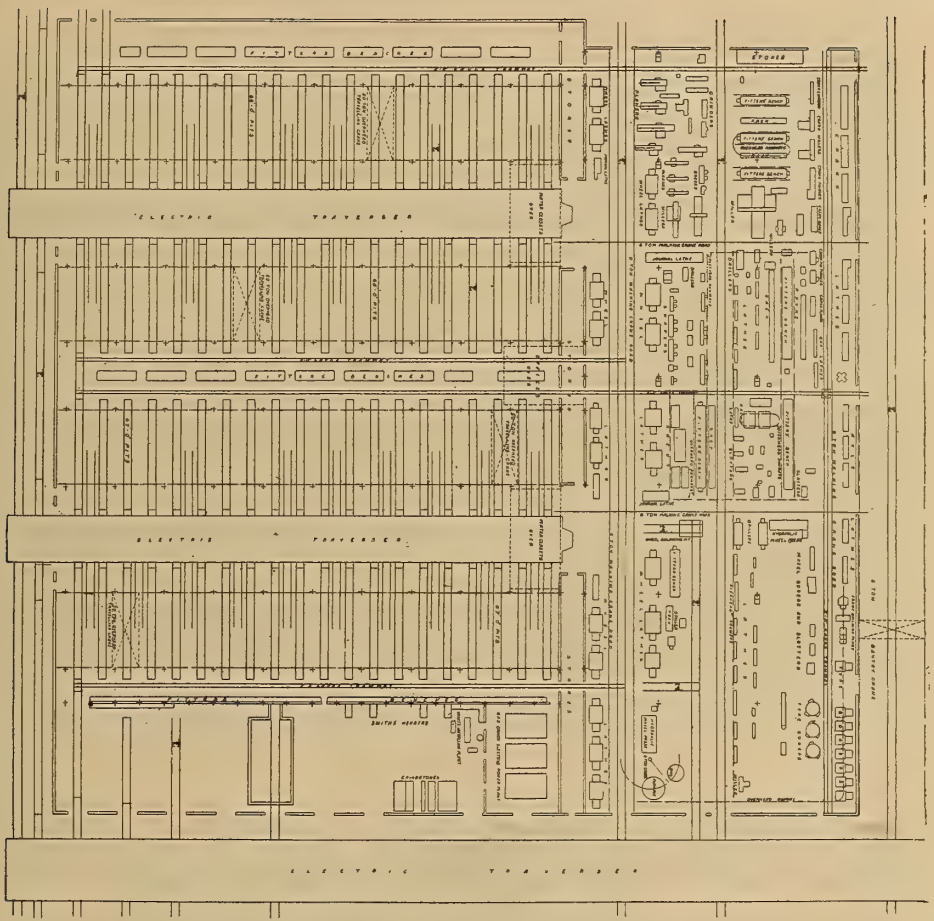


FIG. 8.—PLAN OF ERECTING AND MACHINE SHOPS

ing gear. For small operations pillar jib cranes of 30 hundred-weight or 2 tons capacity are provided, and while not overlapping, are numerous enough to deal with the whole floor space. For smaller lifts pneumatic hoists are most convenient, as these may be slung from any suitable position where required, and connections made by armoured hose to the compressed air main.

The next illustration (Fig. 6) shows a further adaptation of hydraulic power. The vertical jib crane, which has a capacity of 30 tons, is shown with a boiler slung ready for riveting the circumferential seams. The hydraulic riveter has a gap sufficient to take the whole length of the barrel, and the inside and outside firebox seams may be operated on in the same manner. Fifteen hundred pounds per square inch is the pressure used, which gives a load of about 50 tons on the rivet.

Pneumatic tools, while being almost indispensable for certain operations, are not suitable for riveting on boilers, where steam tightness against high pressures is absolutely necessary. The hydraulic riveter, both fixed and portable, with its constant pressure, is found to perfectly fill the hole with the rivet. Pneumatic power is specially suitable in its application to portable drills, chisels, tapping and caulking tools, and as such is very largely employed. The compressed

FIG. 9.—VIEW IN MACHINE SHOP, SHOWING ELECTRIC DRIVING

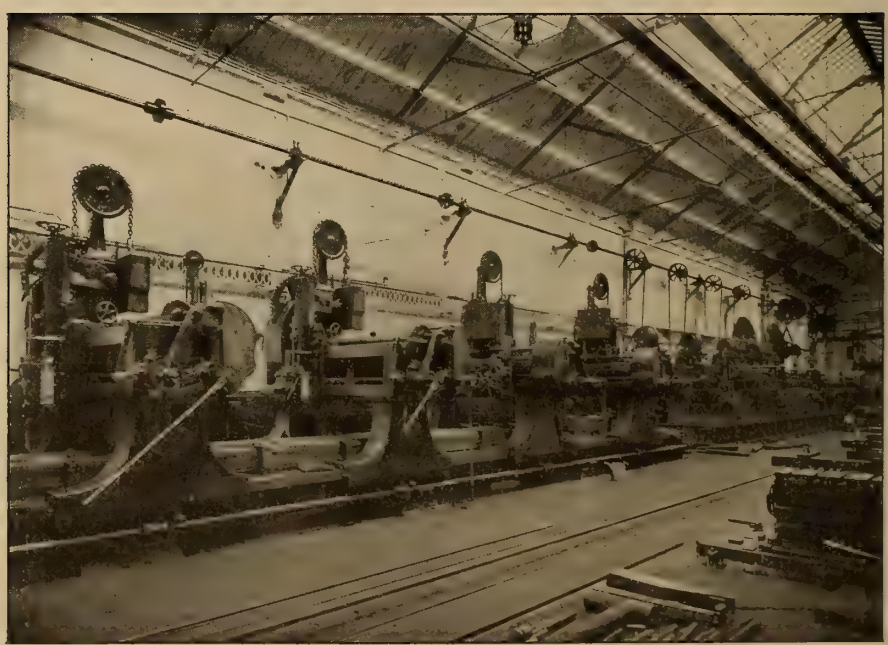


FIG. 10.—FOUR HEAD DRILLING AND PLANING MACHINE. JOHN HETHERINGTON & SON, MANCHESTER

FIG. 11.—BRETT DROP HAMMERS IN THE FORGE SHOP

air main is also tapped in convenient positions and connected by rubber hose for the supply of blast through a reducing valve to the portable rivet-heating furnaces.

The iron foundry with its output of, roughly, 500 to 600 tons of castings per week, of all weights and shapes, requires generous treatment in the provision of facilities for obtaining conveniently its coke, pig-iron, scrap, moulding sand, etc., and for the delivery of the finished castings. For this reason a through road, or roads, is necessary on which the railway track with its raw material may come in at one end and the finished castings be dispatched at the other. A wagon weigh-bridge of 20 tons capacity is necessary on incoming and outgoing roads, and it is also necessary for one of the incoming roads to pass under the charging stage of the cupolas. The usual capacity of the cupolas is 12 tons per hour, the number being increased to suit the total output. For special work and small charges where very accurate composition is required, the air furnace is necessary. A hydraulic lift capable of dealing with 20-ton railway trucks is required to lift the wagon containing coke, pig-iron or scrap to the floor above at the level of the cupola charging mouth.

The blast for the cupolas is used at a pressure of about 18 inches of water, and it is most conveniently supplied by separate self-contained blowers, either motor or engine-driven. The molten metal is "tapped out" at the foundry floor into ladles, the most convenient for ordinary purposes being one of about 6 cwt. capacity, running on its own wheels on a plate floor. For the larger castings ladles of 15 tons capacity are employed, these being carried by overhead electric cranes, with simultaneous lifting and traversing gears

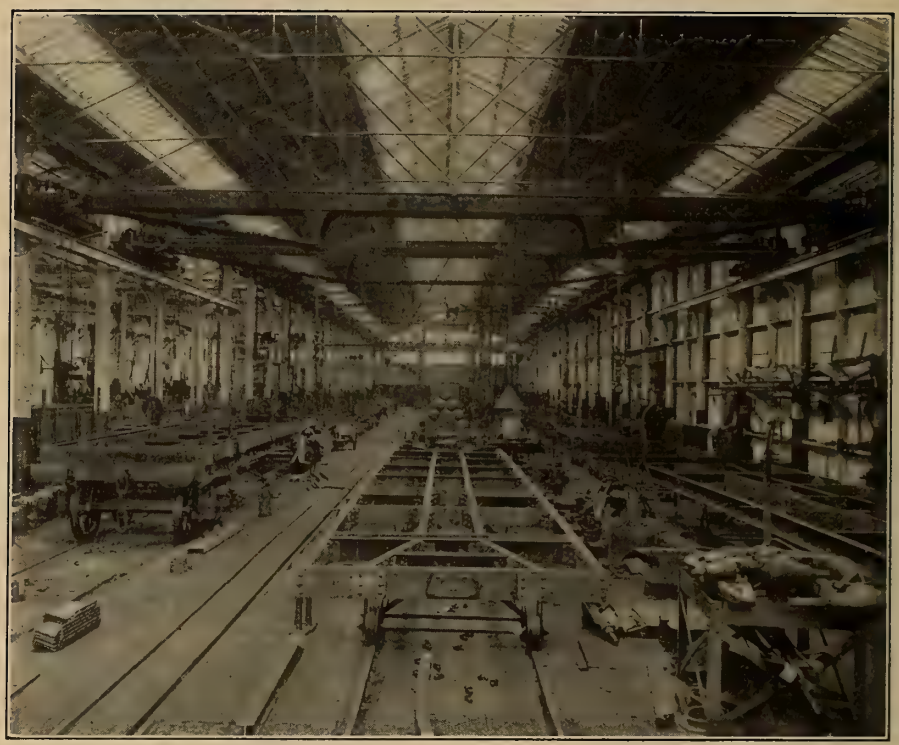


FIG. 12.—VIEW IN FRAME SHOP

capable of dealing with 20 tons. For repetition work, such as axleboxes, brake blocks, small hand wheels, signal gear castings, railway chairs, etc., fixed hydraulic and hand moulding machines are employed; but these fixed machines are gradually being superseded by the traveling hand moulding machine. The illustration (Fig. 7) shows a portion of a foundry served by seven of these machines, and represents one day's output of brake blocks and axleboxes. The machines are worked by two men and travel on their own wheels up and down the rows of moulding boxes. Large castings are cleaned and fettled by hand; but for the smaller work fettling drums are provided, either motor-driven or by belt from a line of shafting. The pneumatic tool as a labour-saving device is again exemplified in the foundry. Larger castings have their rough surfaces and runner marks chipped and cleaned off by the pneumatic chipper, sand is riddled by compressed air, and in connection with the moulding machine, the pneumatic rapper is used in withdrawing the pattern from the mould. Air hoists of about 10 hundred-weight capacity are of service in the lifting and fettling of moderately-sized castings.

The brass foundry, by reason of the different methods in use for melting the metal, is usually separated from the iron foundry and situated in a different building. The different alloys of gun-metal, bearing-metal, brazing metal, bronze, etc., are required in relatively small quantities, and of very accurate composition, which makes the use of the plumbage crucible necessary. These latter vary in capacity from 120 to 180 pounds, and are heated in a coke-fired furnace; but for larger castings and special work the air furnace is used. The majority is repetition work, and the mould is produced either by hand from a plate or on a

FIG. 13.—WOODWORKING SHOP, SHOWING RANSOME BAND SAW AND OVERHEAD TRAVERSER

moulding machine. A fettling drum is required, and for further finishing the sand blast is used, and castings are ground on an emery wheel if necessary.

Many locomotive and carriage under-frame details, such as wheel centres, axleboxes and brackets of different forms, which used to be made of cast or wrought iron, are now produced in cast steel.

As a rule, these articles are purchased from steel founders, and it is not proposed to deal with the steel foundry in this article, although at least one railway company—the London & North Western—produces its own steel castings.

The line diagram (Fig. 8) represents the plan of an engine erecting shop, with machine shop under the same roof, which is of the well-known "weaver" type; the "lights" face north, and, as a result, the light in the shop is well distributed, no direct sun rays and consequent shadows interfering with the workmen. As will be seen, the pits are laid out on the "side-by-side" principle, and are served overhead by four hydraulic-electric cranes, carrying their own pumps for the two 25-ton crabs, each having 2½-ton quick lifts for light work.

It will be observed that the shop is, roughly, of the same length as width. The method of "layout" adopted for erecting pits depends largely on the shape of the ground available. In the case of a long and comparatively narrow shop, this method of layout is obviously not suitable, and the long pit method would necessarily be adopted. Eighty engine pits are provided in four rows, and the capacity is about seventy-five new engines and eight hundred general repairs per annum. The pits are served on the floor by two electric traversers communicating with the sidings outside the shop.

The machine tools used in the

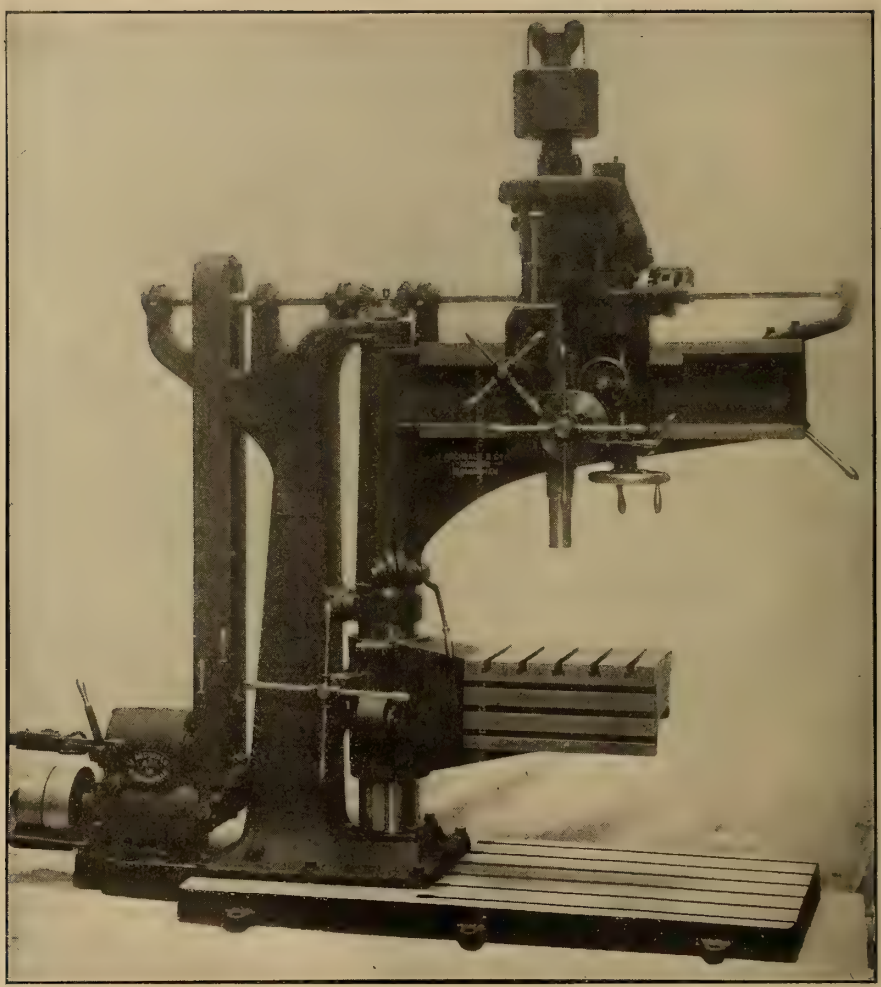


FIG. 14.—IMPROVED HIGH-SPEED RADIAL DRILLING MACHINE. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

actual erecting are few, the work being received from the machine shops practically in a finished state. Holes requiring broaching out and similar work are dealt with by "portable pneumatic," and light riveting is also done by the same means. For larger rivets the portable hydraulic riveter is employed. For "repair" engines the portable pneumatic machine is largely used for reboring cylinders and piston valve bushes, and for facing up the seats of flat valves in position.

In the machine shop, a portion of which is shown in Fig. 9, all the machines are motor-driven, the larger by means of direct gearing, while the smaller are grouped and driven by one motor from a small countershaft. The raw material, such as plates, castings, tires, crank and straight axles, is dealt with by an electric gantry crane outside, which delivers it to the 6-ton electric walking cranes traveling on the roads shown. These cranes have separate motors for traveling and lifting, the traveling speed being about 220 feet per minute with full load. They take up very little floor space, running on a single rail, the crane pillar carrying

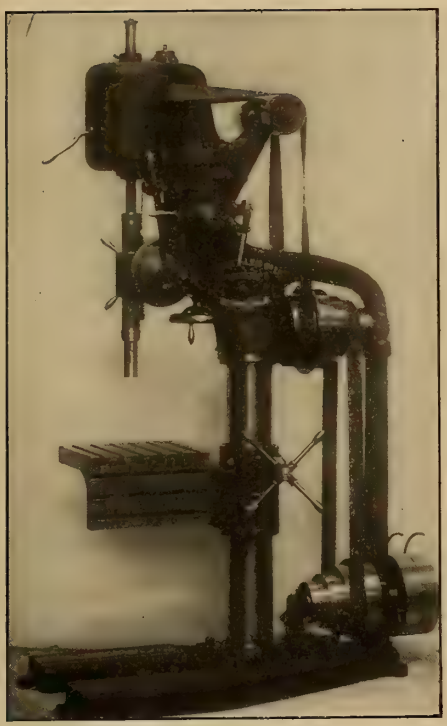


FIG. 15.—HIGH-SPEED DRILLING MACHINE. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

rollers at the top, which bear against an H section girder. The crane man rides with the crane on a small platform just above the rail level, and the ease with which loads are manipulated makes these cranes extremely useful.

For light work, up to about 1-ton loads, overhead runways are provided.

Locomotive tires are always shrunk on and fixed by a retaining ring or by retaining bolts. To expand it, the tire is placed in a ground furnace, preferably gas-fired through ordinary "Bunsen" burners. The diameter of the furnace is about 10 feet, being suitable for the largest size driving wheel used. A 6-ton electric jib crane serves the tire furnace, the anvil for fixing the retaining ring and the hydraulic wheel press. The latter, of sufficient gap to accommodate the longest axle, is coupled to the 800 pounds and 1,500 pounds mains. The wheel is forced on to the axle with a pressure of 90 to 100 tons, but in taking it off the axle for repairs, a pressure of 300 tons is sometimes necessary. For this latter pressure it is necessary to couple up through the ordinary valve box with a small set of motor-driven hydraulic pumps.

For the smaller diameter tires the ordinary vertical face-plate turning and boring lathes are used, but for larger diameters of 6 feet and more the horizontal face-plate boring and turning machine is preferable. In this latter type the vibration inseparable to the large vertical face plate is practically entirely eliminated.

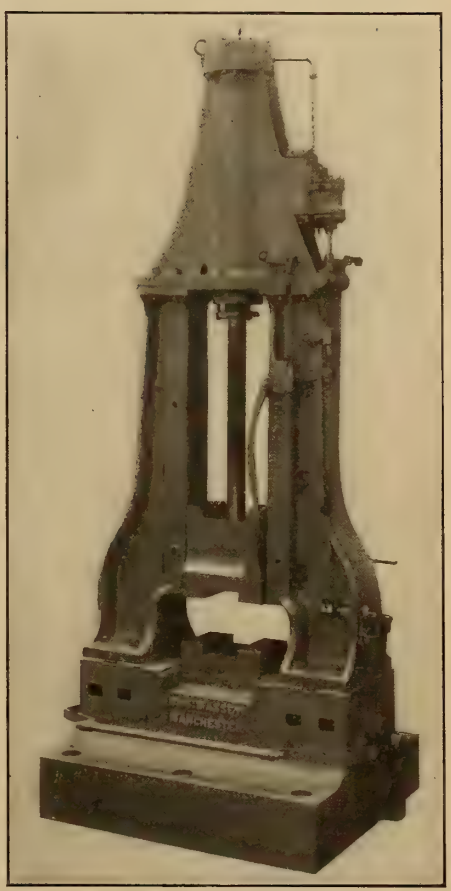


FIG. 16.—STEAM STAMP. B. & S. MASSEY, MANCHESTER

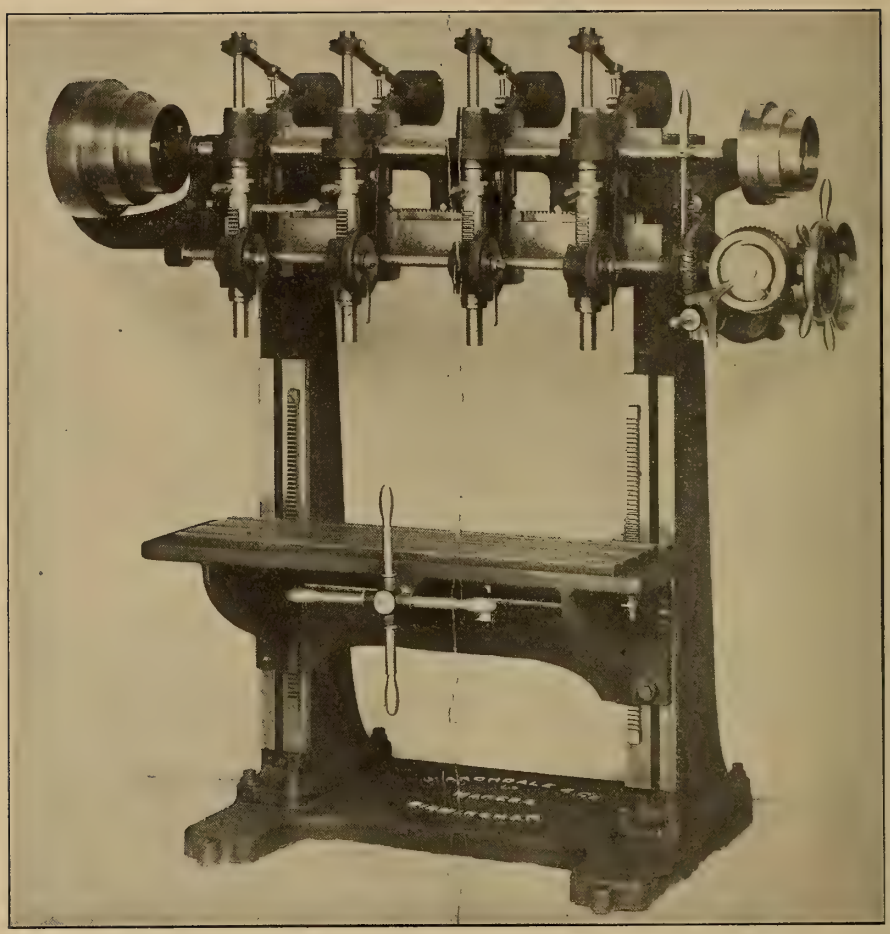


FIG. 17.—MULTIPLE-SPINDLE DRILLING MACHINE. JAMES ARCHDALE & CO., LTD., BIRMINGHAM

With face plate and bed of heavy sections, three tools can be in operation at the same time, and the pressure is resisted directly by the bed on which the plate revolves.

The usual axle roughing and finishing lathes fitted with roller burnishing attachment for journals and crank-pin turning machines comprise the equipment for axles. For cutting the keyway in the wheel seat the ordinary slotting machine is not suitable for large diameter wheels, owing to the vibration due to the excessive overhang of the tool from the bed. A specially designed "key seater" is necessary for this work, with a bed of heavy section. The vertical cutter bar has sufficient stroke for the longest wheel seats, and is carried in three guides, to ensure perfect rigidity. The wheel seat of a locomotive wheel is bored to a very small taper, and to provide for this in setting the tool for depth of keyway the table can be tilted in both directions. One or two quartering machines are necessary for dealing with the driving and coupled wheels of a locomotive after the wheels are fixed on the axle. These machines are specially adapted for boring out the crank-pin holes at right angles to each other. The axle is centered in the fixed headstocks, and movable headstocks on the quarter are ad-

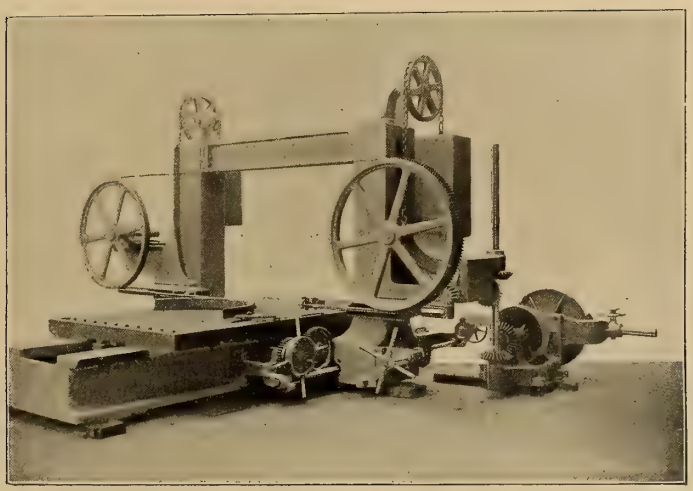


FIG. 18.—HORIZONTAL BAND-SAW MACHINE. NOBLE & LUND, FELLING-ON-TYNE

justable to the "throw" required and fitted with the necessary apparatus for boring taper holes. Cranks for inside cylinder locomotives are now being very largely built up, and machines for their production, and that of axles and "outside" cranks, are necessary. Lathes are required for roughing, facing and boring outside cranks and milling machines for finishing the contours of crank webs.

Milling machines, both vertical and horizontal, are largely used for connecting-rods, coupling rods, regulator handles, extension rods, eccentric rods and other locomotive details. Motion bars, horn blocks and details requiring flat, bright surfaces are finished in the lapping machine, a most useful tool for this class of work. The work is fixed in water in a trough bed which moves horizontally under a revolving emery wheel, and this has a cross traverse. These three motions produce a fine surface-plate finish on the bars, and the emery wheel automatically keeps itself true and parallel.

High-speed tool steel, combined with improved methods of handling work by means of jigs, chucks, etc., and the introduction of automatic machines, has placed modern machine-shop practice considerably in

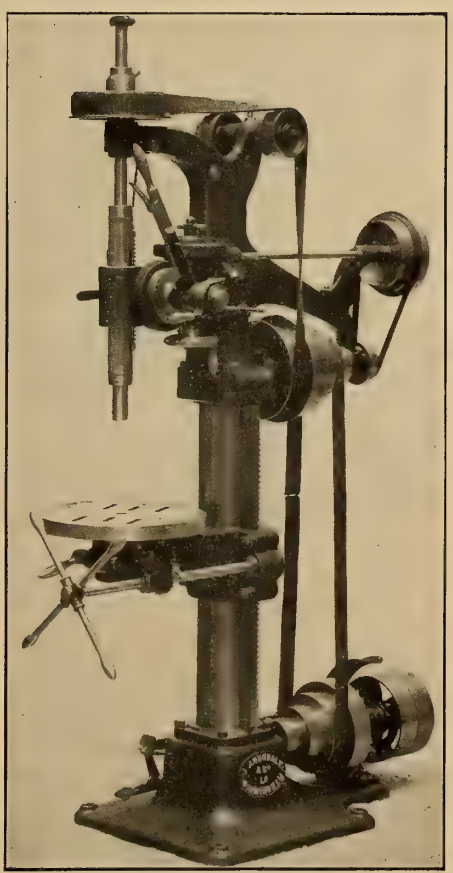


FIG. 19.—IMPROVED HIGH-SPEED DRILLING MACHINE. JAS. ARCHDALE & CO., LTD., BIRMINGHAM

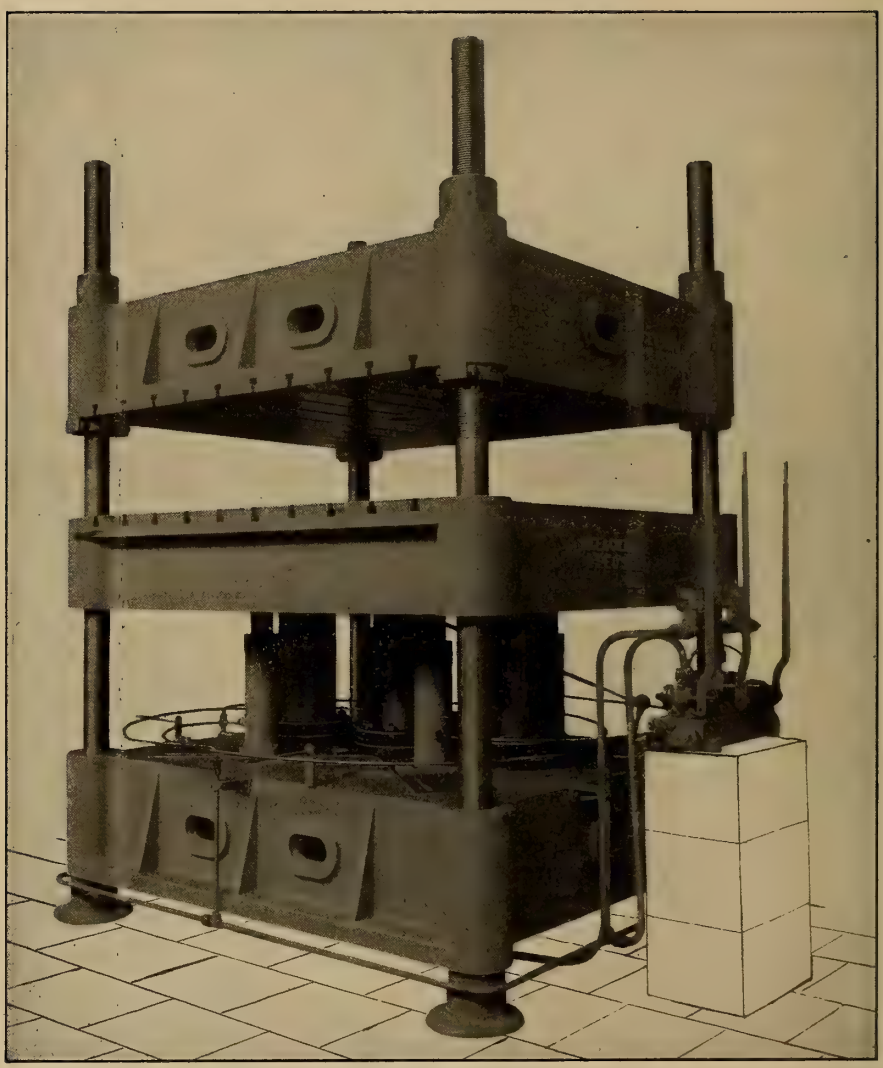


FIG. 20.—LARGE FLANGING PRESS. RICE & CO., LTD., LEEDS

advance of that of a few years ago. The heavier cuts and higher cutting speed have demanded a stronger and heavier type of machine, with well-cut gears and bearings of ample dimensions to resist and eliminate vibration. The automatic machine for repetition work, such as turned bolts from the hexagon bar and boiler studs and stays from the round bar, is invaluable. It is quite usual to see six or eight of these machines under the control of one man, with a boy helper to look after the feed.

The flat turret lathe has all the tools required carried in the various holders, and when once set, these are quickly brought into action. This type of lathe is largely used for the production of pins, special bolts, long boiler stays, valves, syphon taps, handrail pillars, taper pins and a number of other small locomotive details. The more general introduction of the micrometer gauge has made it possible for pins to be sup-

plied direct from the lathe absolutely correct to diameter required, thus obviating the need of repair work being taken to the machine for fitting These improvements all tend to reduce the fitters' work at the erecting pit, to increase the final output, and provide for the interchangeability of different parts.

Piston rods, valve spindles and other rods requiring a bright, true surface are finished by an emery grinder, being first "roughed out" on the lathe.

The main frames of a locomotive are frequently about 40 feet in length. They are usually punched to within half an inch of the finished size, and afterwards either milled or slotted round the edges to a finish, unless the shape of the frame will allow a straight run-through on a planing machine. This work is most efficiently performed on a large, heavy slotting machine of special strength, and capacity to deal with eight or ten frames at the same time. The illustration (Fig. 10) shows a four-head slotting machine working on a set of frame plates about 10½ inches deep and between 30 and 40 feet long. The frames are removed to another four-head machine for drilling. For other work, such as smoke-box-front plates, foundation rings, stay and extension frames, the usual heavy boring, milling, slotting and planing machines are necessary, double-headed whenever possible.

For boring and facing locomotive cylinders, machines of specially heavy design are necessary, either duplex or single, to suit the design of cylinder. The boring bar should be of sufficiently large diameter and tool holder heavy enough to prevent any vibration and give a perfectly true bore from end to end.

For the production of tanks, girders, roof principals, columns, etc., the shop requires much the same equipment as the boiler shop, except that here from the nature of the work the portable pneumatic riveter is more in evidence, although the hydraulic riveter is still generally used for heavy work. Levelling blocks, plate bending rolls, shearing and punching machines, and drilling machines of the multiple type are required if much repetition work is done. Owing to the bulky nature of the work, the floor is preferably kept clear of jib cranes, and the work is best manipulated by an overhead motor-driven traveling crane with a lift of 15 to 20 tons. For light lifts, such as small plates and the slinging of hydraulic or pneumatic riveters in position, the air hoist of 15 hundred-

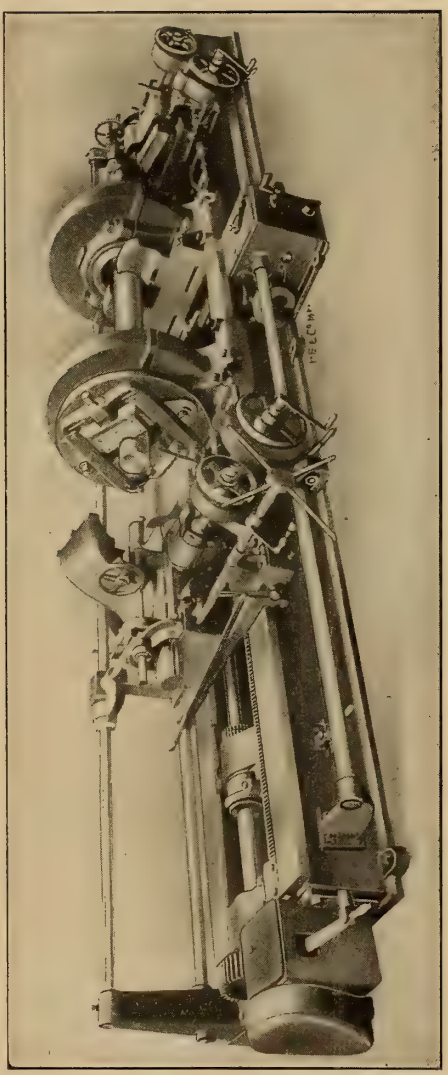


FIG. 21.—AXLE-BENDING AND CENTREING LATHE. JOHN HOLROYD & CO., LTD., ROCHDALE

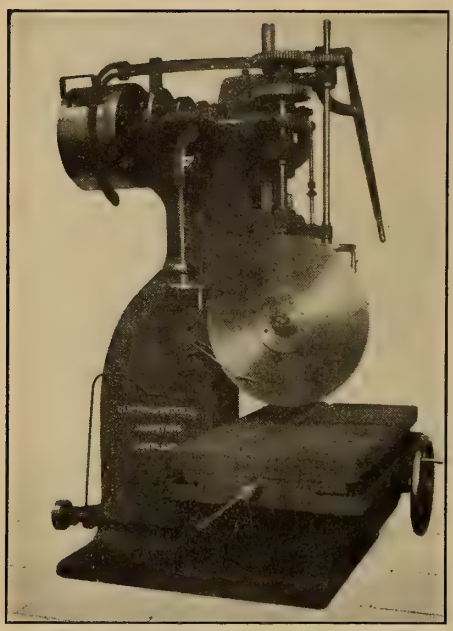


FIG. 22.—VERTICAL COLD SAWING MACHINE. CLIFFTON & WADDELL, JOHNSTONE, NEAR GLASGOW

weight or 1 ton capacity is invaluable.

Commercial sections of angle, tee, H and other bars are usually purchased; but special sections required for locomotives, carriages and wagons, permanent way work, etc., are produced in the railway company's own rail mill. Where possible, the old wrought iron and steel scrap inseparable from a large railway works are worked up under the hammer into blooms and rolled into the required sections.

The manufacture of points and crossings and other special permanent way work requires a shop of ample floor space equipped with the heavy machine tools necessary—radial and multiple drilling machines, planing, slotting and shaping machines, hydraulic straightening machines for rails, cold saws, and numerous overhead runners for lifting purposes.

For the production and repairs of the numerous springs required on rolling stock, the usual spring-maker's furnace should be provided, together with punching, shearing and drilling machines for dealing with steel bars for laminated springs. The plates are bent to shape under hydraulic press, and hydraulic power is also used in pressing buckles on and in removing them from old springs. The springs are given a vibratory test similar to, but in excess of, working conditions in a steam scragging machine, and afterwards tested by direct load for deflection by hydraulic power. For dealing with volute, spiral and other springs, a belt-driven winding machine is provided, the springs being tempered in the usual oil bath.

The perfecting of the drop hammer has revolutionized the methods in use in the forge, and drop stamping now plays a most important part in the production of the numerous standard repetition items in connection with locomotive, carriage and wagon construction. It is claimed, and borne out in practice, that the elastic gravitation blow is peculiarly suitable for the manufacture of such details. The illustration (Fig. 11) shows a battery of twelve Brett drop hammers. The tups range in weight from 5 hundred-weight to 30 hundred-weight, and produce clean, well-formed forgings from a quarter of a pound up to 30 pounds in weight. The tups are raised by overhead lifters, steam driven, and, given suitable dies, there is practically no small detail which cannot be efficiently and cheaply produced. The die, when cut in special tool steel, is good for some thousand impressions, and if the block is deep enough originally, the impression may be planed off when worn and the block re-cut. In this way it is possible to prolong the life of a pair of blocks indefinitely.

The "beard" is either removed under a separate hammer or under the same hammer on a special beard cutter. The latter method is, of course, the more efficient, as it saves the second hammer, and no time is lost in removing the original dies.

Below is a list of work which is daily produced under the "drop":

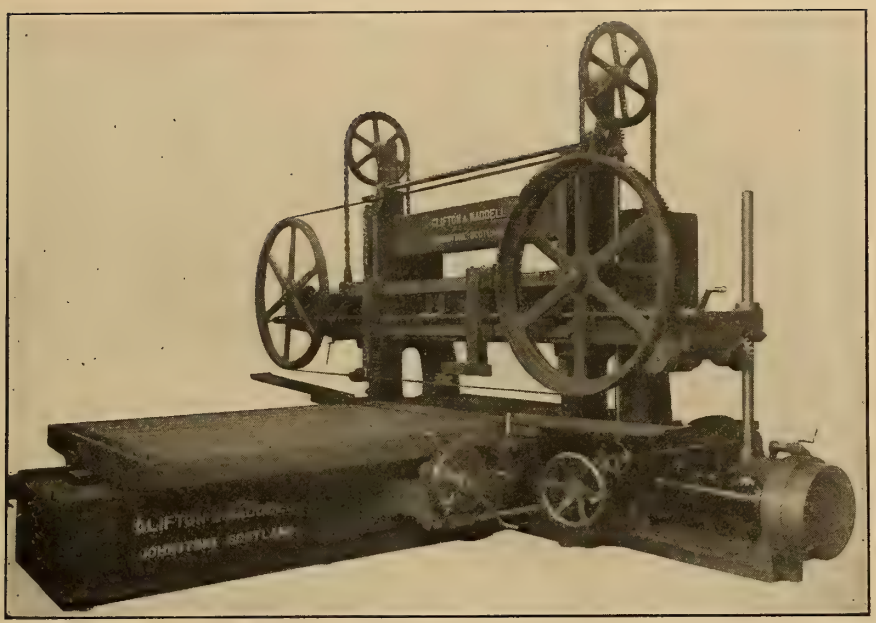


FIG. 23.—HORIZONTAL METAL BAND-SAWING MACHINE. CLIFTON & WADDELL, JOHNSTONE, NEAR GLASGOW

For locomotives—axle-box fronts and lids, bell-cranks and levers, spring cups, brackets for ashpans, brake work, tanks, smokeboxes, etc.; mudhole doors and bridges, links, small crossheads, rod ends, socket ends, special flanges, handles of different patterns, spanners, brake hangers, spring buckles, crane swivels, crane hooks, draghooks, etc.

For carriages and wagons—buffer bushes, brackets, spring buckles, eye bolts, special bolts and clips, scroll irons, tie rod ends, brake cylinder glands, hooks, levers, brake hangers, handles, knuckle joints, trunnions, special washers, etc.

The numerous small forgings used in locking gear, switches, points and crossings, etc., are specially suitable for production under the drop hammer.

For small work the blocks should be cut to produce a number of items at one operation.

For general smiths' work, the pneumatic power hammer of the Massey type is now being largely used. When worked in conjunction with an oil furnace, the installation can be well controlled by one man. The furnace uses a gas works by-product in the form of creosote or oil gas tar, and requires little attention, and the hammer, when actuated by a foot lever, leaves the smith free to handle the work on the anvil block. It will be seen that this arrangement is capable of development, and in certain cases may prove to be even less costly and more efficient than the drop hammer.

The tool shop should be replete with machines for the manufacture and repairs of taps, dies, drills, pneumatic and hydraulic tools, gauges, jigs and templates. It is very necessary that exact temperatures should be attained in the hardening and tempering of high-speed tool steels, and instead of relying on the "eye" of the workman a specially designed furnace is necessary, fitted with a temperature recorder.

A very important department of a railway plant is the testing house, in which are conducted the physical tests of all the material used. It is equipped with machines for taking the tensile strength of steel, iron and

copper plates, axles and tires, breaking strength of cast iron and timber, crushing load of bricks and cement, fatigue and heat tests of rubber, lubricants, boiler coverings, etc. Periodical tensile tests are made of all chains, lifting slings, hooks, etc., used on the railway, and for this purpose a chain pit sufficiently long to accommodate the chains is provided. The pressure is obtained from the hydraulic main, supplemented where necessary by pumps, and is registered by a balanced steel yard. The drop-testing plant for axles, tires, rails, etc., is provided with a power windlass for raising the "tup" to the necessary height, usually about 40 feet.

In addition to the physical tests, the chemical analysis of the different materials is required, and the chemical laboratory is provided with the necessary instruments for carrying out analyses of steel, copper, lubricants, water for drinking and boiler purposes, and the many other materials used or carried by a railway company.

For heavy repetition work, especially in carriages and wagons, the hydraulic forging press is especially necessary. The work produced comprises such things as carriage and wagon buffer guides, spring shoes, scroll irons, stanchions, heavy corner-bent plate brackets, vacuum piston heads, vacuum cylinder covers, trolley wheels, manhole rings and covers, wagon cradles, etc. Hydraulic bending and straightening machines are also required for bending, either hot or cold, heavy girder knee brackets of tee or angle section stanchions, axle guards, etc. These machines are connected to both 800 and 1,500-pound mains, and ram pressures vary from 25 to 200 tons, which may be increased on the larger presses by the intensifier.

Carriage and wagon wheels and axles being of smaller diameter and lighter in weight than those of the locomotive, are dealt with by similar machines, but of lighter design. Modern wagon-wheel centres are usually of cast steel, but the Mansell wood wheel is in fairly general use for carriages. The teak blocks forming the centre are grouped together

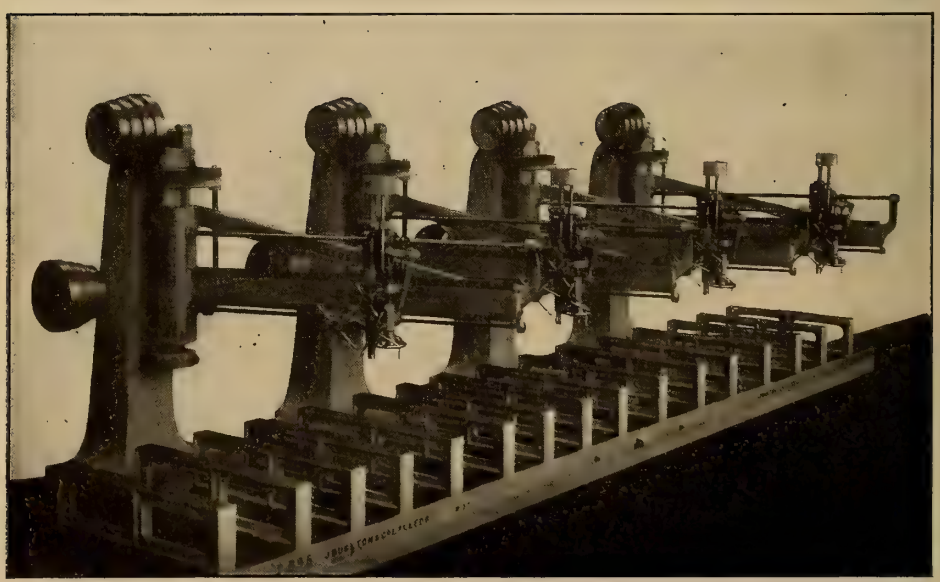


FIG. 24.—MACHINE FOR DRILLING FRAME PLATES. BUILT BY MESSRS. JOSHUA BUCKTON & CO., LEEDS, FOR THE SWINDON WORKS

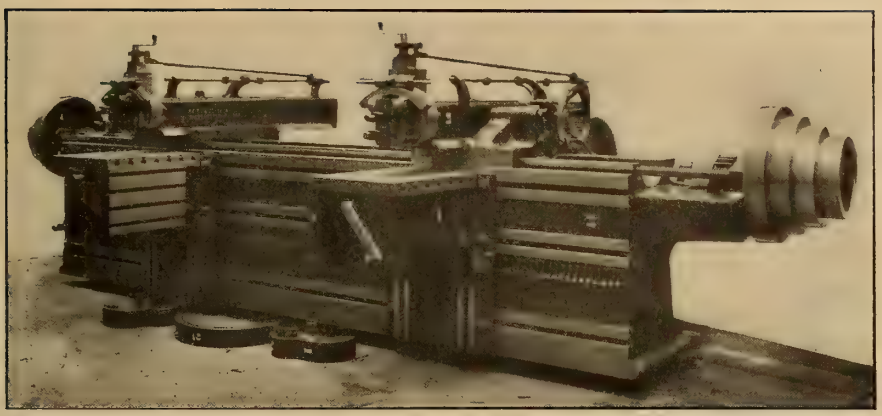


FIG. 25.—DOUBLE SHAPING MACHINE. SMITH & COVENTRY, LTD., MANCHESTER

and drilled for bolts by a multiple drilling machine. To insure easy riding in carriage stock, it is necessary that wheels are perfectly in balance, and for this purpose a wheel-balancing machine is used, which consists essentially of two bearings mounted on elliptic springs, in which the wheel and axle is revolved. Small weights are fixed to the sides of the wheels until vibration is absent when revolving at speed.

For the manufacture of carriage and wagon under-frames the usual heavy machine tools are required, such as vertical, radial and multiple drills, planing, slotting, shaping, milling, punching and shearing machines and plate rolls. Fig. 12 shows a portion of a frame shop. Portable pneumatic and hydraulic riveters are in use and pneumatic drills and hammers. They are carried by the overhead cranes shown, which are hand-driven by rope from the floor level and provided with light hydraulic lifting cylinders.

The bogies under modern carriage stock are made interchangeable, and for facility in repairs and to prevent the undue detention of a coach in the repair shop some method is necessary for readily changing the bogie. This is done either by an overhead crane lifting the carriage body or by a drop pit. The former method has the objections of requiring a shop of sufficient height to accommodate the crane, and also of the liability of straining the carriage body. In the latter case a portion of the shop floor long enough to take the bogie is formed as the table of a hydraulic ram. After being lowered the table and bogie are moved transversely under the floor and raised by a hydraulic ram in a corresponding aperture on the next road. When the old bogie is run off a new one takes its place on the table and the operation is repeated.

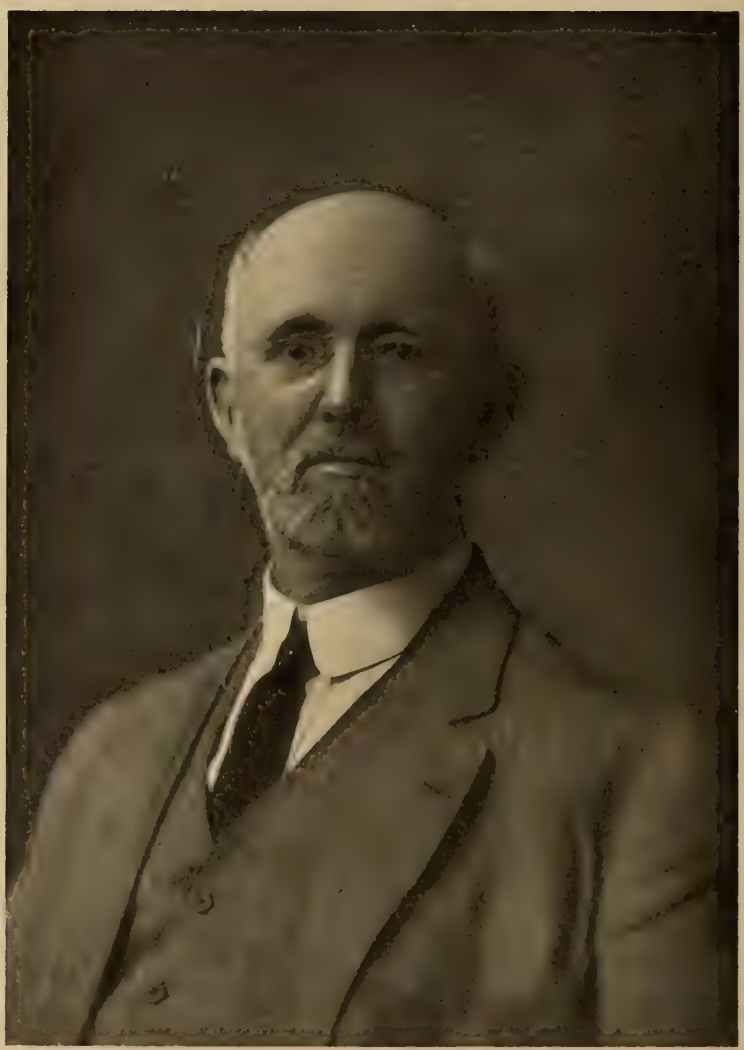
The timber sawmills are provided with heavy vertical log saws, band and circular saws, grooving, tongueing and planing machines. The illustration (Fig. 13) shows a portion of a sawmill with electrically-driven vertical log saw, horizontal band-saw and overhead electric traverser. The cutting speed of the band-saw is 6,000 feet per minute, and the log is fed in both cases by the usual traveling carriage on rollers. The amount of sawdust produced in a large mill is considerable, and the most convenient method of dealing with it is by a fan suction through large tubes communicating with the pits under the floor. It is used for fuel for boilers in a specially designed grate or for other purposes, as desired.

Carriage doors, frames, lights, mouldings and other details are, as far as possible, made in standard sections, and the usual labour-saving machines for their production are

required. They comprise circular, fret and band-saws, general joining, moulding, sand-papering, mitering, mortising and planing machines and wood-turning lathes. For the production of carriage trimming, seats, etc., numerous sewing machines, band-saws and cloth-cutting machines are necessary, preferably electric-driven.

In these days of high traveling speeds it is imperative that the loads on axles of locomotives and carriages should be carefully adjusted. For locomotives, a weighbridge, with six double tables having "dead" plates of suitable width between, will deal with a twelve-wheeled engine and all other wheel arrangements at present in service. Each double table should be capable of weighing up to 25 tons and preferably be supplied with vertical indicating dials for convenience of reading when adjusting axle weights.

For carriages, two tables are necessary, the "dead" plate in this case being necessarily of considerable width and the tables being "pitched" to suit the bogie centres of the modern long carriage.



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PROFESSOR OF MECHANICAL ENGINEERING IN YALE UNIVERSITY

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CASSIER'S MAGAZINE

AN ENGINEERING MONTHLY

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TWENTY-ONE YEARS OF BRITISH WAR SHIPBUILDING

By Archibald S. Hurd

IN CASSIER'S MAGAZINE of August, 1908—before the so-called "British naval crisis" of last March—the present writer ventured to prophesy that "whatever may be the immediate future of shipbuilding generally, those firms throughout the world which make a specialty of warship construction—guns, armour, armaments, engines, boilers, etc.—have before them a period of unparalleled activity. The prospective requirements of the leading naval Powers are more excessive than ever before, not forgetting the almost feverish building for Russia which preceded the outbreak of war with Japan, when the yards of Great Britain, France and the United States were laid under contribution." Since these words were written, the British Parliament has authorized a building programme for one year only far exceeding in number of units, and still more in total cost, anything hitherto dreamt of. This programme comprises eight battleships or battleship-cruisers, costing on an average two millions each; six second-class cruisers of 4,808 tons displacement; twenty destroyers of over 1,000 tons displacement, and about ten submarines. At the same time, Germany had somewhat accelerated the rate of normal naval construction laid down in the Naval act, and she put in hand at an earlier period than was anticipated the work on four large armoured ships, two second-class cruisers, the twelve destroyers, and a number of submarines, forming her programme for the present financial year. Russia has laid down four battleships of the largest size, and the United States has begun the building of two battleships, five destroyers, four submarines and four fleet colliers; while, on the other side of the Pacific, Japan has commenced two more large battleships, two protected cruisers of 4,800 tons and four destroyers, and Italy has commenced one battleship embodying the all-big-gun principle and completed arrangements for beginning three more at early dates; and other navies have not been inactive, although the Austrian project for building four Dreadnoughts has been indefinitely postponed.

This activity on the part of other naval authorities will inevitably lead to a further expansion of warship building in Great Britain, where the standard of naval strength is not absolute, but relative. Unlike other navies, the British fleet has no fixed establishment. Its strength is based upon the interpretation by the gov-

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ernment of the two-Power standard; in other words, it is laid down that the fleet must be equal to the next two greatest naval Powers with a margin of 10 per cent. over for emergency. This standard applies only to battleships, and the Admiralty have consistently held that in cruisers and torpedo craft, owing to the position held by the British merchant marine, the margin of safety must be even higher. It consequently follows that, as the strength of Continental navies is augmented, so the pressure of public opinion upon the British Government results in an expansion of the British naval forces.

This has been illustrated effectively by recent naval history. On relinquishing his position as First Lord of the Admiralty in the Unionist administration, Lord Cawdor issued a memorandum, in the course of which he stated that "at the present time strategic requirements render necessary an output of four large ships annually, and unless unforeseen contingencies arise this number will not be exceeded. The period of building is to be two years, and, therefore, four ships will be laid down each year and there will be eight ships in course of construction in any one year, either in the dockyards or by contract." It is interesting to recall this statement, because it has been entirely falsified as a prophetic announcement of policy by subsequent events. In 1906, immediately following this memorandum, three large armoured ships only were, as a matter of fact, laid down; in the following year the number was three again, and in 1908 only two were authorized.

This experience indicates the fatuity of the authorities of a country with a two-Power standard attempting to prophesy as to the requirements of the future, and it also reveals in sharp outline the difficulties which embarrass the great private firms in meeting the requirements of the Admiralty. Those requirements are never known for twelve months ahead. The two-Power standard is something like the barometer in a private house. The movement of the mercury does not depend upon the wishes, intentions or plans of the householder, but upon outside influences beyond his control. So in the case of the two-Power standard the Admiralty's demands are entirely dependent upon foreign activity. Owing to the introduction of the all-big-gun principle in the *Dreadnought* and the consequent delay in foreign shipyards, the Admiralty considered that in 1907 and 1908 the requirements of the navy would be met by two large ships only in each of these years, and thus the symmetrical shipbuilding plan framed at the end of 1905 was completely broken down. Private shipbuilders, who had calculated on receiving orders for the construction of large armoured vessels, basing their anticipations on the specific statement in the Cawdor memorandum, found, as a matter of fact, that no shipbuilding orders in the armoured class were available for competition, as the two ships in each year were only just sufficient to provide employment in the two government dockyards—Portsmouth and Devonport. As the government yards are not manufacturing establishments so much as places of assembly and construction, the material was provided by the great private firms of England, but they lost the work represented by the process of construction.

After these two years of leanness the British people were dramatically shaken out of a state of complacency by the sudden demand by the government for the immediate commencement of four large armoured ships and for authority to prepare for the building of four more, apart from cruisers and torpedo craft, while tenders have since been invited for two large armoured ships for the Pacific, to be paid for by the Australian Commonwealth and New Zealand, respectively.

Thus in a period of a few months the demand upon the great private shipbuilding establishments in Great Britain rose from zero to a point hitherto unapproached in the record of British shipbuilding. The Admiralty announced that two of these eight large ships of upwards of 20,000 tons each would be placed in the government dockyards, and that, whereas the great private firms had received no orders for armoured ships for two years, they were to be suddenly called upon to tender for the practically simultaneous production of eight. Not only this, but it was laid down that the work should not be done at an easy or convenient pace, but that each of the eight ships should be completed within a period of two years from the signing of the contracts. Nothing could illustrate more forcibly the evils inevitably associated with such a two-Power standard as has hitherto been more or less consistently acted upon by the British naval authorities. It results in a complete absence of continuity of construction. One year the establishments may be running at the highest pressure and difficulty may be experienced in obtaining sufficient labour, and the next year the naval orders are so few, or absolutely non-existent, that firms would find the greatest difficulty in providing employment even for a nucleus staff in certain trades were it not for the orders which many of them usually succeed in securing from foreign countries.

As was almost inevitable when the unprecedented demand by the Admiralty for the eight Dreadnought ships in the British Government's own programme was put forward, public opinion immediately jumped to the conclusion that British resources would prove unequal to the strain which was about to be put upon them. Wild statements were put into circulation as to the facilities which existed for coping with such large orders, but none of these statements have so far proved well founded. Probably in the whole range of industry nothing is more remarkable than the spirit in which all the various firms associated with warship construction have always responded to national demands. Whatever feelings they may have entertained during the lean years, when their machinery and plant have lain either idle or inadequately employed, they have never nursed their grievances when the time of emergency has come. Before the surprising development of Admiralty policy was announced in March it was assumed, certainly on the Continent of Europe, that after so long a period of comparative inactivity in warship building in private establishments the greatest difficulty would be found in coping with a sudden expansion. As a matter of fact, whatever minor difficulties may have been experienced, the great private firms have proved more than equal to the new situation. Two vessels of the largest armoured class were begun within a few weeks of the passing of the shipbuilding vote, one—the *Colossus*—being laid down at Scott's yard, Greenock, on July 19, and the other—the *Hercules*—at Palmer's yard, at Jarrow-on-Tyne, on August 5. Two more ships have since been laid down at Portsmouth and Devonport government dockyards, and shortly before the Parliamentary session ended the First Lord of the Admiralty was able to announce that the Admiralty had made arrangements which would ensure the completion of the other four ships of the programme by March, 1912, while this year contracts have been placed for the two Colonial armoured ships. In other words, within a few months of the sudden demand by the Admiralty and the Colonies for two large armoured ships the great private firms of Great Britain had given undertakings that, so far as their staffs and resources were concerned, these vessels would be built within the period stipulated—namely, two years from the date of commencement. No allied industries

have ever responded with more splendid spirit to the demands of a government department. The manner in which the new conditions were met is fresh testimony to the organizing capacity of the captains of industry who are associated with the building and equipment of warships.

The emergency, however, does illustrate in a striking manner the immense difficulties under which these various industries are conducted in Great Britain owing to the unevenness in the flow of orders. Fortunately, there is now every prospect that for some years to come the shipbuilding resources of the whole country will be fully employed. Already a demand has been put forward in various quarters that in the coming financial year another eight Dreadnoughts should be laid down, together with half-a-dozen more second-class cruisers and at least twenty destroyers, besides submarines. In view of all the circumstances, the Admiralty will certainly not repeat in the coming financial year the shipbuilding programme which startled the world in March last. The maintenance of the two-Power standard does not justify such a programme.

In view of this renewed activity in warship building in Great Britain, it is interesting to glance back over the period of twenty years which commenced in March, 1889, when the Naval Defense act was introduced. On page 660 is printed a carefully compiled statement of the ships which have actually been laid down for the British fleet during this period of twenty-one years. This statement does not give the shipbuilding programme of the several years, because on more than one occasion these have been varied by the Admiralty even after they have been approved by Parliament. Since the beginning of the present century no less than seventeen destroyers, five cruisers, armoured or otherwise, and one battleship have thus been abandoned, thus occasioning further disappointment to private firms, because all this work in normal circumstances would have come to them rather than to government establishments. The statement of shipbuilding during these twenty-one years is not only absolutely authentic in all its details, but there is reason to believe that no such full and detailed compilation has hitherto been published, and it will no doubt prove of value for purposes of reference. It is also of considerable present interest from the light which it throws upon the absence of continuity in shipbuilding policy. In no two years has the demand by the Admiralty upon the shipbuilding resources of the country corresponded; sometimes the orders have been large, sometimes they have been small. This variation is not revealed in all its completeness by the mere numerical tabulation of units, because the character of these units has changed. A first-class battleship under the Naval Defense act of twenty-one years ago would not be regarded as a first-class battleship to-day. Under the Naval Defense act the Admiralty laid down battleships of 14,000 tons which cost from £770,000 to £892,000, whereas in the latest naval estimates the total cost of an armoured ship, including guns, is shown to vary from £1,624,000—the phenomenally low price of the battleship *Vanguard,* of 19,250 tons, building by Messrs. Vickers Sons & Maxim, at Barrow-in-Furness—to £1,765,000 for the battleship *Bellerophon,* of 18,600 tons, built at Devonport dockyard. Moreover, even the *Vanguard* is exceeded in displacement, and, therefore, probably in much more cost also—though official figures are wanting—by the new ships of the improved Dreadnought class which are now under construction and which will displace upwards of 20,000 tons. Consequently, a battleship to-day represents considerably more than twice—indeed, practically thrice—the cost of a battleship twenty years ago, and there is even a greater disparity in vessels which are now styled

"armoured cruisers." These ships, owing to their immense size, high speed and heavy guns, are even more costly than the latest battleships, and represent nearly twice the expenditure which was incurred in the construction of such colossal and, at the time, swift, protected vessels as the *Powerful* and the *Terrible*.

The tabular statement also shows that not a single first-class protected cruiser has been laid down since 1896; that from this same year down to March, 1908, only three second-class cruisers were built, and in the same period only seven third-class cruisers were authorized. It is unnecessary to emphasize the bearing of this falling off in construction in the several classes upon the arrangement of work by private shipbuilders. The inconvenience to trade would not have been so serious if there had been a corresponding expansion in the construction of destroyers. This, however, has not been the case. Whereas in the seven years 1893-99 one hundred and eight destroyers were ordered, in the seven years ending 1906 only forty-eight destroyers were laid down, apart from a number of torpedo boats, twenty-four of which were of a particularly large type styled "coastal destroyers." Some compensation has been found in the orders for eighty-four submarines which have been placed since 1901; but these boats, representing a specialization of ship construction, have been built entirely by one firm who have devoted special attention to this branch—Messrs. Vickers Sons & Maxim—until the last few years, when a few vessels have been laid down in the Royal dockyard at Chatham. The tabulated statement shows that the two periods referred to—namely, 1889 to 1900 eleven years, and from 1900 to 1910, ten years—the following vessels have been constructed or laid down for the British fleet.

	Battleships	Armoured Cruisers	Protected Cruisers	Destroyers	Torpedo Boats	Submarines
1889-1900 (11 years)	38	14	80	108	12	..
1900-1910 (10 years)	30	25	18	89	47	84
	68	39	98	197	59	84

Total, ships of war	545
Add 8 scouts, 18 torpedo gunboats, 6 gunboats and 14 sloops	46
Grand total	591

In these twenty-one years, consequently, including eight scouts of about 3,000 tons displacement, eighteen torpedo gunboats, six gunboats and fourteen sloops, 591 ships of war have been laid down for the British fleet. Apparently the construction of ships has been less active in the last ten years than in the preceding period of the same length; but this conclusion is entirely falsified when the increase in the size of the various naval units is borne in mind. Nothing indicates the growth in the cost of warships of various types better than the official figures given below, showing the extent of the outlay upon new ships.

During the period from 1889 to 1901 the sum spent on the work contemplated reached a total of £67,436,118, or an annual average of £5,619,676. In this work the government dockyards, of course, shared. Since 1901 the average expenditure on new construction has amounted on the average to just over £10,000,000 annually. In this work the dockyards have again shared, in addition to carrying out all the general repairs of the fleet, except for one

*STATEMENT SHOWING ACTUAL EXPENDITURE ON NEW CONSTRUCTION

For Five Years	
From 1871-72 to 1875-76	£6,424,666
From 1876-77 to 1880-81	9,367,407
From 1881-82 to 1885-86	11,359,135
From 1886-87 to 1890-91	17,771,066
From 1891-92 to 1895-96	22,909,890
From 1896-97 to 1900-01	35,565,136
From 1901-02 to 1905-06	49,466,793

TWENTY-ONE YEARS OF BRITISH SHIPBUILDING

	Battle-ships	Armoured Cruisers	First Class Cruisers	Second Class Cruisers	Third Class Cruisers	Destroyers	Torpedo Boats	Submarines
Naval defense act, 1889-94	10	0	9	29	4	0	0	0
1892-3	3	0	0	0	0	0	10	0
1893-4	0	0	2	3	0	20	0	0
1894-5	7	0	0	6	0	42	0	0
1895-6	0	0	4	4	2	0	0	0
1896-7	5	0	4	3	6	28	0	0
1897-8	4	0	0	0	3	2	0	0
Supplementary programme, 1897	0	4	0	0	0	4	0	0
1898-9	3	4	0	0	0	0	0	0
Supplementary programme, 1898	4	4	0	0	0	12	0	0
1899-1900	2	2	0	1	0	0	2	0
Totals, 1889-1899 (11 years)	38	14	19	46	15	108	12	0
1900-1	2	6	0	1	0	5	2	0
1901-2	3	6	0	0	2	10	5	5
1902-3	2	2	0	0	2	9	4	4
1903-4	5	4	0	0	0	15	0	10
1904-5	2	3	0	0	0	1	0	10
1905-6	1	3*b*	0	0	0	6	12*c*	11
1906-7	3	0	0	0	0	2	12	12
1907-8	3	0	0	1	0	5	12	12
1908-9	1	1*b*	0	4	2	16	0	10
1909-10	8	0	0	6	0	20	0	10
Totals, 1900-9 (10 years)	30	25	0	12	6	89	47	84
Grand totals	68	39	19	58	21	197	59	84
Ships lost or removed from active list.	1	0	0	10	5	14	0	1
Net totals	67	39	19	48	16*a*	183	59	83

a This does not include 8 scouts (1902 and 1903).
b These four ships are Dreadnought cruisers of the Indomitable type.
c Originally these 36 craft were known as "coastal destroyers." They displace from 247 to 287 tons, and have speeds of from 26 to 28 knots.
Eighteen torpedo gunboats were also built, and 6 gunboats have also been constructed, as well as 14 sloops, of which one has been lost and several sold.

short period when this work fell in arrears, and the Admiralty, as an experiment, placed certain ships in private yards for overhauling. When it is borne in mind that every addition to the number or size of ships in the fleet has involved a corresponding increase in the repairing work required, some idea may be formed of the actual increase in the shipbuilding and repairing resources of Great Britain which must have taken place in the past decade in order to enable the government and private establishments to respond to the increased and very irregular demands.

The character of the task cannot even be accurately judged from figures, because this has been a period of transition in naval construction. Particular attention was directed to this aspect of warship building in the report of the committee appointed to inquire into the arrears of shipbuilding, which was published in 1902. In this report notice was directed to developments in armour and boiler manufacture with which shipbuilders have had to contend, and which a few years ago led to delays in delivery:

(1) *Armour.* In 1896, it is recorded, the results obtained by Messrs. Krupp with modifications of the Harvey process, showed such superiority in resisting power that it became necessary to raise the standard for the armour required for H. M. ships. The armour-plate makers had only just completed the extensions and alterations of their works to fit them for making "Harveyed" armour when this new demand was made. Having already incurred very large capital expenditure on plant and machinery, still further outlay was necessary. "It is satisfactory to note," the committee recorded, "that the great establishments in the country undertook the new and arduous duties thrown upon them with alacrity and courage. Their schemes included provision for a considerably enlarged output as well as for the superior quality of armour. They were necessarily dependent to a large extent upon sub-contractors for the machines, lifting appliances and en-

gineering details of all kinds required by these changes. All these items of work were very seriously affected by the labour difficulties with the engineers in 1897-8, and the same difficulties prevented the full utilization of the available plant, as the engineers engaged on armour manufacture ceased work to a great extent."

(2) *Boiler Tubes.* The general adoption of water-tube boilers in all classes of warships, the committee added, resulted in a great demand for tubes of high quality, capable of passing special tests. This fact would have involved delays for a time in delivery of materials, and "we were informed that the difficulty was increased by the simultaneous demand for large quantities of tubes needed for bicycles, for which purpose less stringent tests sufficed. In order to obtain the necessary strength, the tubes were required to be solid drawn, for which special appliances were required. At first no restriction was placed on the use of any steel for this purpose, provided suitable tubes were produced. But it is stated by the Admiralty that when one firm, which was entrusted by several contractors with large orders for these tubes for many important ships, failed to make satisfactory tubes of material which they believed was Swedish steel of good quality, and thereby led to considerable delay in the completion of the boilers of those ships, Swedish steel was then excluded for a time from all such work and English steel only was insisted upon. Good tubes can be produced either from suitable English-made steel or good Swedish, but not every quality of either English or Swedish steel is suitable for the purpose. After a time, on tube-makers' representations and guarantees of good quality, the restriction as to English steel only being used was rescinded. Special tools were also required for staving, machining and screwing the tubes for Bellevue boilers."

(3) *Marine Turbines.* Since this committee's report was issued the British Admiralty decided, at an early stage in the development of the marine turbine, that the reciprocating engine for ships of war was doomed. Since the laying down of the battleship *Dreadnought,* in October, 1905, no reciprocating engines have been ordered for any British man-of-war. At the time the action of the Admiralty in fitting the *Dreadnought* with this new type of engine was regarded by many engineers as little short of madness. The bold experiment has been justified in the result, and great strides have since been made. Whereas the *Dreadnought,* with a displacement of just under 18,000 tons, had turbines corresponding to 23,000 indicated horse-power, and the three battleship-cruisers of the *Invincible* class were required to indicate at the contractors' full-power trial 41,000, the fourth ship of this class has advanced to 45,000, and a further vessel is in early stages of construction at Devonport dockyard of even greater power. On her trials the *Dreadnought* attained a speed of 22.84 knots—a rate of steaming hitherto unattained by any battleship; while of her swifter sisters of the same period it is reported that the *Invincible* has reached 28.6 knots, the *Inflexible* 27.4 and the *Indefatigable* 28.7. These results bear sufficient testimony to the success with which British engineering firms responded immediately to the Admiralty's demand for high-power machinery.

If we may judge by this past record of British shipbuilding, engineering, armour-making and gun manufacturing firms, the outlook suggests that, however heavy the demand which the Admiralty may make upon them in the near future, they will not prove unequal to the strain. Never have any industries revealed such conspicuous elasticity and resourcefulness as these firms during this period of transition in the matter of armour, boilers and engines.

IRRIGATION AND ENGINEERING

By D. A. Willey

THE engineer has, perhaps, been afforded a better opportunity to display his skill and ability in the execution of projects for the public benefit in America than in any other portion of the world. This is largely due to development of a new country and the important changes which are taking place by reason of such development. In opening up territories to the settler the railroad is essential for transportation of the people and their requisites. With the coming of the railway is associated the building of the mill and factory, usually the nucleus of the town or city. The industries depend on the variety and abundance of the natural resources, such as timber, soil suitable for agriculture, ore and coal deposits.

There must be something to cause any development, with its movement of people, its investment of capital; but the man who plays the most important part—the man whose expert knowledge is relied upon by the capitalist and promoter—is the engineer. Not a rail would be laid, not a stone or brick set in a building, not a dollar placed in any business venture in the United States, unless the investigation of the engineer as to the resources of the region is accepted as favourable. In short, he may be called the monitor upon whose work and conclusions the adoption or rejection of an undertaking depends.

No more striking illustration of the importance of the engineer is presented than in connection with the great engineering work connected with the American irrigation schemes. The magnitude of this activity has given an opportunity, possibly unparalleled in the past, to test the ability of the men versed in the construction of dam and reservoir formation, electric power generation and distribution, hydraulic power, the volume and head of water in rivers, and the available supply of the watersheds serving these streams. The work of the civil engineer in mapping the topography of the country, locating sites for reservoirs, estimating the descent of rivers and the contour of watersheds, should be included in this discussion, since it is so closely associated with the constructive features of the water storage and distribution systems.

To give a clear conception of the achievements of the engineer in the reclamation of arid lands for crop production, some statistics should be noted of the great scope of the series of projects. Nearly eight years have passed since the United States went into the business of turning the water upon the land, and up to date it has spent 48 million dollars. This money has been invested in twenty-eight projects, meaning dams, reservoirs, canals, machinery and the payroll of the 12,000 workers in the irrigation service, from the engineers who surveyed the rivers and lakes, estimated the flow of water and planned the works to the dollar-a-day man who fills the hundred miles of canal, serving a thousand acres, merely by twisting the wheel valve that lifts the water gate. Sixteen large rivers and seven lakes have been restrained

to supply water to the arid lands in their vicinity, and at the present time 1,250,000 acres of reclaimed desert are being tilled and supporting 125,000 people.

If we include the areas cultivated by irrigation provided by individuals and corporations independent of the government system, we have a total of 10,000,000 acres in the United States made productive by the reservoir and canal, which would be barren if dependent on the moisture from the local rainfall. The government had good reason for making irrigation a national project, since the success of the farmers in independent irrigated districts is such that from the 8,750,000 acres of the arid region alone comes an annual crop revenue of over $100,000,000. The projects now under way controlled by the reclamation service in the arid and semi-arid States have made such progress that in the year of 1911 will be recorded a total area of 2,00,000 acres of land served in these sections by the government water distribution systems, making a grand total of nearly 11,000,000 acres.

From the engineering standpoint the private enterprises must be considered as noteworthy, since they would have been impossible without the engineer. It may be stated that some of them are of remarkable magnitude. There are four regions of the United States in which irrigation is utilized—the arid region, comprising those States and Territories in which agriculture depends almost entirely upon irrigation; the semi-arid region, lying midway between the Rocky Mountains and the Mississippi River, where the rainfall is uncertain; the rice-producing States, comprising parts of Texas, Louisiana, the Carolinas and Georgia; and the humid States, represented by several of the New England, Middle Atlantic and Gulf States, where there is a limited amount of irrigation. A government report of irrigation in the United States in 1902 showed that in the arid States and Territories 8,471,641 acres were under irrigation; in the semi-arid States and Territories, 403,449 acres; in the rice States of the South, 606,199 acres, and 5,788 acres in the humid States, making a total for the whole country of 9,487,077 acres. The number of farms included in these systems were 134,036, and the total cost of irrigation $93,320,453. Practically the whole of this work has been done by private enterprise. It includes irrigation of every kind, from the ambitious scheme of the large corporation down to the individual irrigation ditch of the small farmer.

The projects of the government for the storage and distribution of water under the Newlands irrigation law of 1902 are unparalleled in their extent, and form an interesting study of the efficiency of the American engineer. Of the 28 storage and distribution systems now being completed, each presents individual problems difficult of solution. Not a few are located far away from the nearest railway, so that the question of transporting machinery and supplies must be answered. In other cases no timber is available for false work, cribs or other construction, and a substitute must be provided for it. A favourable site for a reservoir may be so situated that it can only be supplied or its water distributed by tunneling through hill and mountain, owing to the topography of the region. The volume and head of water in some of the rivers serving the reservoirs and the rapid rise and fall of certain rivers are other factors to be given careful consideration, especially in the building of dams and retaining walls, in order that they may have sufficient strength to withstand the impact of the flood currents.

In illustrating the important accomplishments of the engineer in the reclaiming of the waste lands, one of the projects cited should be what is called the Roosevelt, since it is by far the greatest from an engineering standpoint yet undertaken in irriga-

HANGERS FOR THE OUTSIDE FORMS OF THE SOUTH PINTO PRESSURE PIPE, SALT RIVER, ARIZONA

tion engineering, exceeding the modern Egyptian, the ancient Babylonian, and any of the others under way in America. This provides for the creation of a reservoir to be served by the Verde and the Salt Rivers. There is a history connected with the location of Roosevelt. In 1902 a little party of dust-covered men dismounted from their burros in the Salt River valley. It was not an inviting spot—the place where they pitched their tents. True, Salt River flowed near by—a shallow stream

thick with what had once been alkali dust blown into it by the desert winds. Unfit to drink, the river water was suitable only for washing, and they had to slake their thirst from the casks in the water wagon. Their food came from the backs of the pack ponies, for not a thing to eat could they get in this region.

Forty miles from anywhere, meaning even a single human habitation, this group of engineers existed in that desolate valley long enough to measure its width, the height of the cliffs forming it on either side, to study the rock strata of the sides. They drilled holes in the river bed to determine the thickness of the solid rock. Then finally they pulled the tent pegs, packed up their surveying kits and started back into the world. These men sighted the sextant, stretched the measuring tape and pounded the rocks with their geologist hammers, to learn if that rift in Arizona could be walled, because right here in the desert was an opportunity to direct the forces of Nature to the use and convenience of man. This rent in the earth, if barred, would cause the Salt River and branches to swell until they would be turned into a lake, and this lake could be made to turn the waste into a land of plenty.

The valley of the Salt River is so situated as to form one of the most arid portions of America. Yet such has been human faith in the ability of the engineer and, above all, in the modern system of irrigation, that the world's greatest water supply works is now being created on the site chosen by the engineers. The dam will form a storage basin holding sufficient water to flood 1,300,000 acres to an average depth of one foot. This quantity is much larger than the volume held in storage by the greatest Nile reservoir. Verde and the Salt Rivers, furnishing the supply, drain a watershed of 6,260 square miles. The average yearly rainfall over this drainage basin is not over 20 inches. The annual rainfall upon the territory to be irrigated ranges from 3 to 10 inches, and the rapid evaporation of moisture is indicated by the fact that the temperature in summer ranges as high as 120 degrees, although the elevation varies from 1,000 to 1,300 feet altitude. The dam will impound sufficient water to fully irrigate 270,000 acres of soil.

Work upon the construction of the dam proper has been in progress only since September 20, 1906, owing to the immense amount of labour required in making the excavations to bed rock. When it is remembered that the height of the dam above the rock is 284 feet, the length at the bottom 235 feet, and the length at the top 1,080 feet, the time and labour required in preparing the site for the wall do not seem excessive. The work is what is technically known as a masonry arch dam with a gravity section arising from the foundation. It will range in thickness from nearly 175 feet at the bottom to 16 feet at the top, a width sufficient to provide a highway for vehicles.

An enormous quantity of rock set in concrete is required for filling in behind the face of the barrier, and boulders as large as can be handled are used. Nearly 400,000 cubic yards of masonry will be placed in position when the dam is completed, and the reservoir which it will create will form a lake 25½ square miles in area. As soon as the dam is finished the cement mill and other construction plants will be stripped of all machinery which can be profitably removed and the buildings abandoned, as they will be many feet under water when the reservoir fills.

The power at Roosevelt is obtained independently of the irrigating scheme, through a power canal 20 miles in length, which was one of the first works completed. This canal, which is distinct from the reservoir, develops a head of water that actuates waterwheels connected to electric generators. From the

CONSTRUCTION WORK ON THE SALT RIVER DAM, ARIZONA

power station extends a transmission line conveying current to the plant for the manufacture of cement, the stone-crushing plant, for lighting, operating the aerial railway, and for other purposes. Under a head of 250 feet, hydraulic jets with nozzles of 11 inches have been used to wash away the loose formation and accumulation of sump above the bed rock upon which the dam proper is being built, and have greatly facilitated progress. Much of the gravel thus secured has been utilized for construction material. To remove the gravel, elevators have been placed in service.

This canal is one of the permanent works. Most of it is lined with concrete, and it includes several tunnels, aggregating nearly 10,000 feet in length. It is carried over gulches by concrete pipes. The dams used for diverting the water to the power canal represent a cost of $40,000, while the canal, including its pressure pipe and auxiliary structures, represents a total of nearly $1,000,000. With all of the generating sets to be installed in service, it will develop no less than 4,400 horsepower, which will be used for pumping water for irrigation after it is not required for actuating machinery in building the dam.

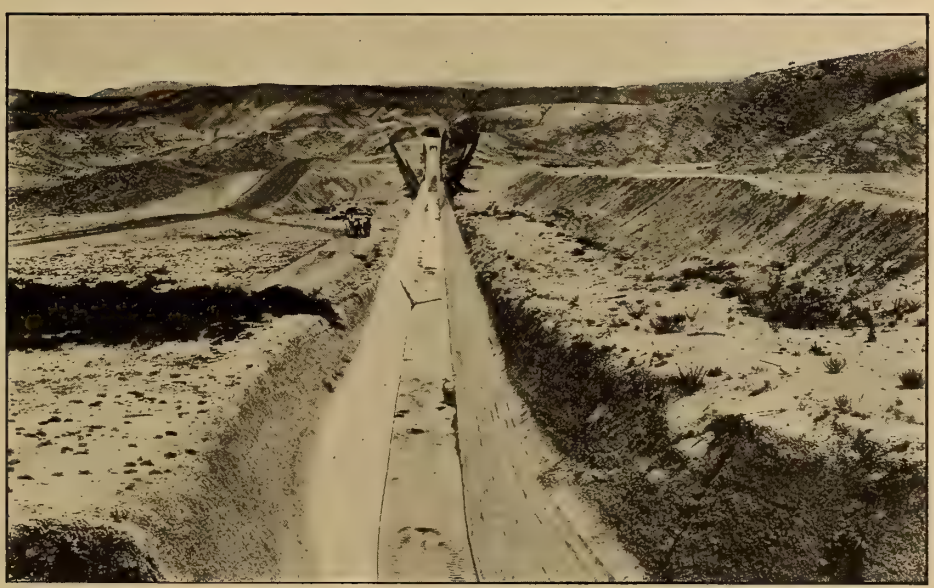
An interesting feature of the work is an outlet which has been constructed through the walls of the canyon a distance of 500 feet. This tunnel will not only carry off much of the surplus water, but also the silt which is brought down the channels in such large quantities during flood height. The question of removing this silt was solved by the engineers by planning the tunnel in question. The current through it will be so rapid that it is believed the sediment will thus be removed without difficulty. The tunnel contains no fewer than six gates, which will be required to regulate the flow of

the water. They are built to be operated under a pressure of 100 pounds to the square inch, and, including their operating mechanism, will weigh in the aggregate nearly 400 tons.

The diversion dam to be constructed 30 miles from the main dam is almost as important in connection with the reclamation of this section of Arizona as the construction at Roosevelt. Work has been in progress upon this for over a year. It is intended to keep the water of the rivers at a certain level, and will increase their depth to the extent of 15 feet over the present low-water average. An idea of the dimensions of this dam can be gained when it is stated that it will be nearly 1,300 feet long, and will require 40,000 cubic yards of concrete before it is completed. A distributing canal is being built in connection with regulating gates, which will have a flow of at least 2,000 feet per second. This is situated upon the north side of the dam. Another canal, with the capacity of 1,000 feet per second, is being constructed on the south side. The site of this operation is at what is known as Granite Reef, about 30 miles from Phœnix. It will furnish the water by means of electric pumps, the service covering 40,000 acres.

Truly it seems incredible that men could believe such a project as the Salt River could be undertaken successfully, but already it has gone so far that time only is needed to make it a fact. Were it merely the effort of human toil it would be an impossibility, but this vast work is an illustration of the triumph of mind over matter. We may mention a few other reasons why the site was chosen. This part of Arizona has such an undulating surface that, as the water is carried from storage by irrigation canals and ditches, it will flow over the land by gravity, and actually irrigate the soil as far away as the city of Phœnix, 78 miles distant.

Thus the irrigation can be done by the forces of Nature, as the reservoir is to be at such an elevation. The investigators bored in the valley to find how hard were the rocky sides and bed. They discovered that the dam could have a foundation of rock by blasting away the top of the.



A CONCRETE-LINED CANAL ON THE GUNNISON PROJECT. THE CONCRETE MAKES A CHANNEL THROUGH THE SAND POSSIBLE

river bed, and that the face of the cliffs could be blown out with explosives, thus removing all the loose material until a solid formation was reached into which to set the ends of the dam and bind them with cement. The dimensions of the structure had already been completed on paper, and they knew they must have mechanism to lift and move the stone blocks, to handle the thousands of tons of rock and earth to be excavated, as well as for other purposes. With the nearest coal mine almost a thousand miles away and the nearest railroad a hundred miles distant, coal would make steam power out of the question, and the wood in the vicinity was not sufficient for engine fuel. Then came the idea—why not water-power? They found that by going up the valley they could divert a part of the river into the canal described, through which the water would flow with such a head that it could be used to generate a powerful electric current. So the Roosevelt dam is actually being erected with the aid of the rivers which it is to conserve, and by mechanical methods a few hundred men are doing a work beside which the building of the Great Pyramid was a small undertaking.

In planning reclamation schemes and determining sites for dams and conduits, the engineers have been obliged to make descents into unexplored gorges and to suffer hardships that characterize their works as acts of heroism. One of the most notable feats successfully accomplished was the location of what is known as the Gunnison project. By it the waters of a stream flowing through the Gunnison gorge, in Southwestern Colorado, have been diverted into the Uncompahgre valley, in the same State, in a volume sufficient to irrigate no less than 200,000 acres.

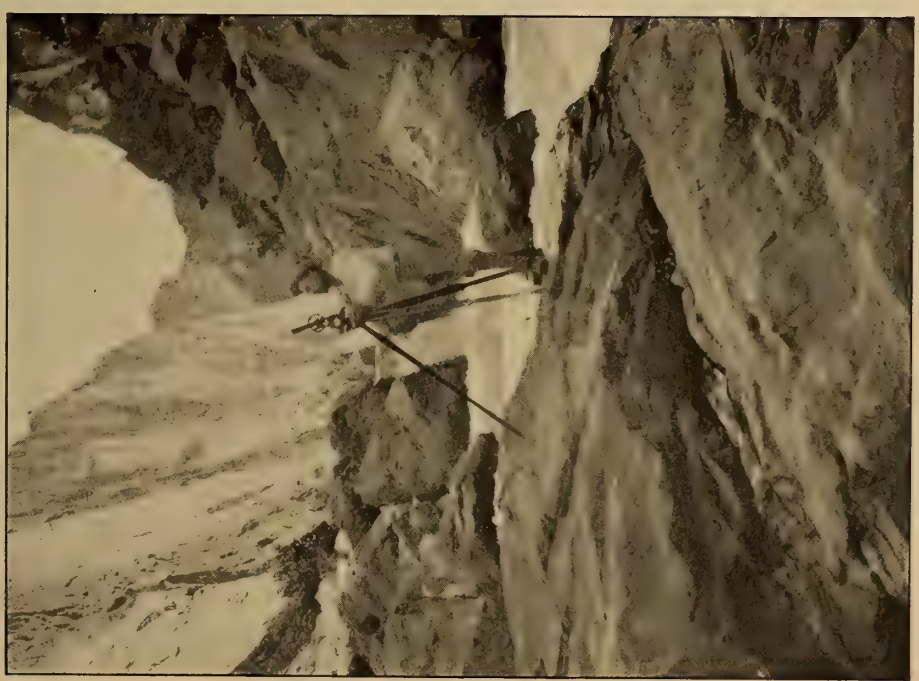
While it was necessary to make what is the largest irrigation tunnel in the world to divert the river, the route of the tunnel was determined under extreme difficulties, for the reason that it is situated in what is known as the Black Canyon, which varies in depth from 1,000 to fully 3,000 feet, the walls in many places being almost perpendicular, while the gorge narrows here and there to a width of less than 50 feet. Consequently, the surveys necessary were made with great difficulty as well as danger.

When the engineers of the reclamation service in this district were ordered to locate a route, an expedition was organized. This descended into the upper gorge, but was only able to make its way a few miles when it reached a point where boats could not be used and the supplies were exhausted. The party then retraced its steps, and after much difficulty climbed out of the canyon, although the sides are so steep that it was necessary to use ropes to make the ascent as well as portions of the descent.

Not discouraged, however, two of the engineers determined to resume the exploration. Entering the head of the canyon, they covered the route of the first expedition. Here they worked their way by climbing over rocks, wading, swimming where necessary, and at one point actually passed under a natural bridge formed by a fall of rock in the canyon. At another point they were obliged to swim a waterfall nearly 20 feet high, but in each case escaped with their lives, although hurled by the rushing torrent against the rock ledges and boulders in the stream and badly bruised. In all, no fewer than ten days were taken in going through the gorges, and the engineers were the first white men who have ever explored what is known as the Black Canyon and returned alive in spite of the channel, which causes rapids, even whirlpools, where an expert swimmer could not survive.

Messrs. A. L. Fellows and W. W. Torrence, the engineers who performed this remarkable feat, were successful in keeping their instru-

SURVEYING IN THE BLACK CANYON; THE ENGINEER HAS TO CLING TO THE ROCKS



ENGINEER A. L. FELLOWS MEASURING THE HEIGHT OF A WALL OF THE GUNNISON CANYON

ments unharmed, and secured measurements to locate the Gunnison end of the proposed tunnel at what is now known as River Portal. The next step was to make this place available for excavation work; also, to provide a site for the power house, since the entrance to the proposed tunnel was directly in the side of the wall, with no ledge or other outcrop below it. A road to carry machinery and other material was absolutely necessary, so the first work done was to construct a thoroughfare 12 miles in length from the valley over the mountain wall and to the proposed entrance. The building of this road in itself was a remarkable engineering feat. Up the Uncompahgre side the road winds as any other mountain road; but on the other slope parts of it had to be blasted out of solid rock. In places it drops down as much as 22 feet in 100. Over this road was hauled all the machinery for the power house, the rails, wire, motors and cars for the tunnel, all the building material and food supplies for the town, and hundreds of tons of coal.

The construction of the tunnel was attempted by an independent corporation; but such were the difficulties, owing to the hard formation and other obstacles, that the work was abandoned. It is to the credit of the United States engineers that they took up the work and finally succeeded, completing a task remarkable for not merely the labour but the danger involved.

Although the formation in places is very hard, no less than 8,500 feet of the tunnel have been completed in a single year, while an average of over 700 feet in a month has been attained. In the progress of the work, however, the excavators have met with unexpected obstacles. In the western section a blast opened the channel of an underground stream of water, which poured into the opening and compelled the men to flee for their lives. Such was the flow of water that it was necessary to make test borings to discover its extent, and a conduit had to be made to drain it. The subterranean opening was filled with carbonic acid, and compressed air had to be forced into the tunnel to prevent the labourers from being overcome.

Intense heat affected the excavators to such an extent that an air shaft 400 feet deep had to be sunk from the surface to ventilate the heading. This required three months of work alone, during which operations in the tunnel had to be postponed. In another part of the excavation a bed of shells and sand fully 500 feet in depth was encountered, necessitating extensive shoring and propping with timber. Here occurred the most serious accident in the progress of the work—a collapse of the false work, confining thirty-two men in the heading. Fortunately, the air pipe was not injured, and during the three days and nights that they were imprisoned they were kept from suffocation by this means. When rescued, it was found that six were dead, having been killed by masses of falling rock.

The tunnel is the third longest in the United States, two railroad tunnels only exceeding it. The volume of water it will carry can be estimated when it is stated that the interior has a diameter of no less than 12 feet. It will deliver a volume of water estimated at 1,300 cubic feet per second, and serve an area embracing over 200 square miles. Connecting with it is a series of canals, most of them lined with concrete, provided with suitable water gates and sluiceways. It has been under the supervision of Mr. I. W. McConnell, of the reclamation service, with Mr. C. T. Pease directly in charge.

Where the topography of the country is such that the hill and mountain sides afford natural walls for the storage of water, the engineer is aided in building his reservoir, as in the Salt River valley and other places

where the stream emerges into the low country through canyon or gorge. A very difficult proposition which has been successfully accomplished by the reclamation service is the building of works for conserving the water supply in rivers which run through a favourable formation and where most of the barrier must be entirely artificial. A notable instance of this is the Yuma project. It is intended to irrigate an extensive territory located in the Yuma valley and bottom lands adjacent to the Colorado and Gila Rivers in the States of California and Arizona. These water courses provide an abundant supply for the area to be irrigated, which for the present will comprise about 100,000 acres. The topography of the country and its formation make the work of constructing dams, canals and suitable storage reservoirs unusually difficult, as there is no natural formation of which engineers can take advantage as in many other portions of the West where are rock walls which can be utilized in storing the water supply. The Colorado River has for years been forming a bed for itself, annually carrying down an immense amount of silt in solution, which is deposited along its course. The channel of the Gila is somewhat similar to the Colorado, and this stream also is subject to very sudden and extreme changes in the volume of water.

VIEW OF CONCRETE HEADGATES, FACE OF IRRIGATION TUNNEL AND METHOD OF RAISING AND LOWERING GATES

The problem to be solved was how to secure a foundation for the levees and other works, and a form of protection against the flood waters which would prevent the barriers from being badly damaged, if not entirely washed away, by the flood currents. The plan adopted was decidedly unique from an engineering standpoint, as it was decided to de-

pend upon earthworks, reinforced by wooden dams or abatis, to check the flow of water against them. When it is stated that the levees considered necessary will extend a distance of nearly 75 miles on the Colorado and Gila Rivers, an idea of the magnitude of this work alone can be gained.

The diversion dam or Laguna dam, as it is called, will extend for a distance of 4,780 feet across the Colorado at a point 12 miles from the town of Yuma. Owing to the friable foundation of the river channel, the dam is of enormous width in proportion to its other dimensions, being 267 feet wide on the bottom, although but 19 feet in height. It will require 356,000 cubic yards of concrete to complete and have a displacement in the water equal to the weight of 600,000 tons. This may be called the main work. Before operations were begun, however, it was necessary to build a very extensive coffer-dam as well as other temporary barriers, to drain the river bed, so that a foundation could be laid. Work was also commenced upon the levee protections referred to, and the project has progressed to such a point that it has been thoroughly tested by exposure to flood currents, with the result that no damage of importance has been done to either the concrete structure or the protecting banks.

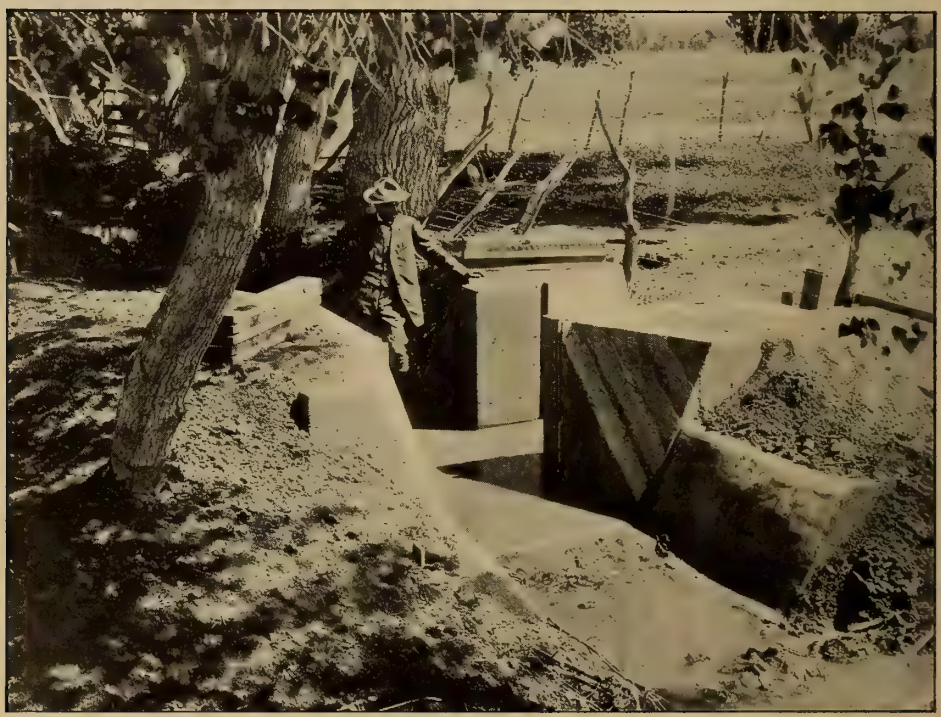
The extensive mileage of levees is partly necessary to protect the main irrigating canals, of which there will be one on each side of the Colorado. The canal on the Arizona side will be 16 miles in length, the one on the Colorado side 10 miles in length, making a total of 26 miles and serving 138 miles of laterals, by which the water will be distributed over the bottoms. The water will enter the canals through concrete and steel gates, while pumping machinery will be installed at several points, where it will be necessary to raise the water supply to a higher level to serve the laterals. It is calculated that the dam, which is the only one of its kind in this country, will be of sufficient capacity to fill the main storage reservoir, which will have an area of 10 square miles. The dam is known as an India weir dam, being of a design which has been very successfully employed in East Indian irrigation, where it is usually constructed of wood.

In building the dikes or levees much of the labour is done by scrapers and plows drawn by horses, as the soil, being stoneless and soft, can easily be heaped up and graded to the proper level. The work of building these levees is quite similar to the artificial embankments formed to restrain rivers in the South, the width at the bottom usually being several times the width at the top, although the crest of the embankments is ample to permit the building of railway tracks here and there, thus using it as a transportation route. As the quantity of concrete required would be so great that it would be far too expensive to use in protecting the levees, and deposits of natural stone are too far distant to be employed, the main defense of the levees against the flood currents, as already stated, is woodwork in some form. This is obtained from timber tracts in the vicinity. Young trees are used extensively, the trunks being cut into suitable lengths and used for the foundation of the matting or abatis. This foundation is fastened securely together, and upon it laid smaller limbs, their ends pointing up and down stream like the fascines of ancient fortifications. Bunches of brushwood and shrubbery form the next layer, being worked in among the boughs beneath. In another form of wooden framework posts are driven into the earth deep enough to secure a firm foundation, in which they hold rigidly. Then a sort of fence is made by nailing limbs of trees from post to post. The face of this fence is further protected by driving piles into the earth in front of its upstream face. Both in the front and rear of the fence are arranged layers of boughs and

DETAILED VIEW OF AVALON DAM, SHOWING RIVER SECTION UNDER CONSTRUCTION

brushwood, sometimes covered over with earth and sometimes left bare.

These dikes are intended not only to protect the embankments, but to be land makers. Each extends outward from the levee a certain distance into the river channel, but at such an angle that it will catch driftwood and other flotsam which may come down the stream. This material will be piled against it, and, as the mass enlarges, it will constitute a stronger barrier against the flood. The idea is similar in some respects to the jetties which have been constructed at various points on the Mississippi, not only to lessen the course of the currents and eddies against the embankments, but to restrain the débris on the surface, thus using it as a reinforcement to the bank, preventing it from becoming a dangerous menace when the river is in flood. One of these levees has been completed from the town of Yuma to the site of the dam, and its brushwork defenses have been finished for a distance of about 7 miles. Another levee has been completed from Yuma to the Mexican boundary, a distance of 20 miles. This section has already been called upon to resist several floods in the Gila, and has withstood the impact of the waters without a break, although it contains no stonework whatever, and its composition, including its dikes, is merely earth and wood.



CONCRETE-LINED LATERAL USED FOR DISTRIBUTING WATER OVER IRRIGATED LANDS FROM MAIN CANAL

In completing plans for the Yuma system, the engineers in charge had to consider another difficult proposition—how to free the water in the rivers from the detritus which is held in solution at all seasons of the year, especially during high water. If the canals were to be filled directly from the rivers by the usual head gates, such a deposit would be carried into them and their branches that frequent excavation would be

necessary to keep the ditches from being filled. As the water distribution in this way would be impracticable, the plans decided upon included arrangements for intercepting the deposits carried in solution to such an extent that the water entering the canals will contain but a small percentage, even during the flood season. While the Laguna dam will divert the water of the Colorado into the main canals described, it will be really of more importance in forming what might be called a settling basin. Here the velocity of the current will be restrained and a pool formed permitting such precipitation. But the brushwood dikes described will also be an important adjunct in this respect, especially during high water. They are not intended to prevent the water from flowing through them to a certain extent, but to check the current. During this operation much of the detritus, it is expected, will be caught against the dikes, and thus they will serve to filter the streams. Nowhere is presented such a remarkable example of water storage without the use of hard formation, and the Yuma is indeed a proof of engineering ability in an extraordinarily puzzling situation.

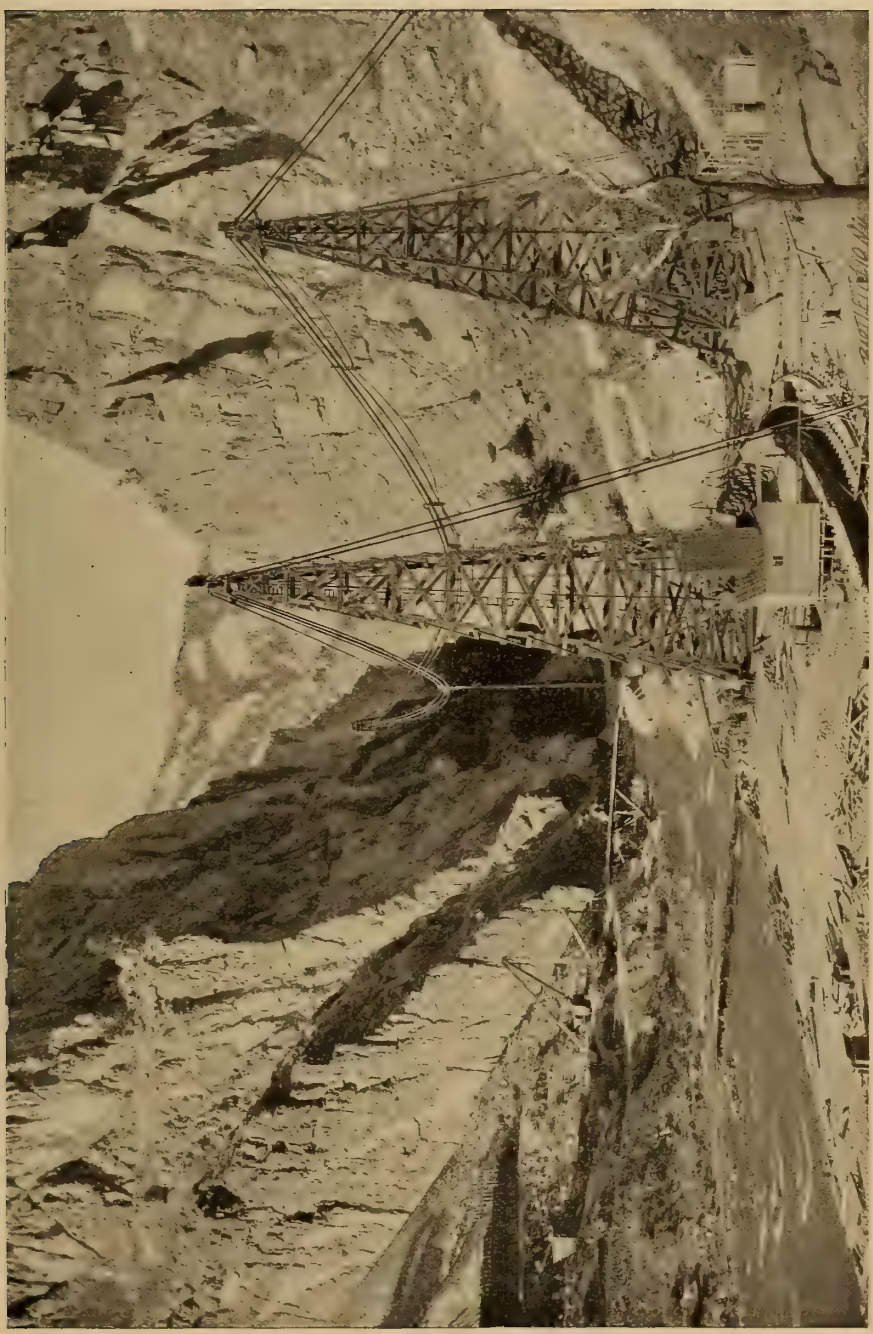
Wherever possible, however, the engineers of the reclamation service have taken advantage of the natural formation afforded in reservoir construction. It may be said that every stream running through a gorge so situated that the waters can be used for irrigation by gravity has been carefully examined. Mr. Frederick H. Newell, the present chief of the service, made a personal investigation of the West when the government took up this work by authority of the Newlands bill. As a result, many of the principal projects have reservoir sites with natural walls,

A CONCRETE IRRIGATION AQUEDUCT

thus avoiding a great expense for construction and permitting a greater scope in irrigation works. In addition to the Roosevelt already described, private enterprise has constructed a dam in the Modesto region of California, creating a reservoir that has reclaimed 250,000 acres of arid lands for the production of fruit and vegetables. Residents in that section of the State became impressed with the importance of having an artificial water supply. They engaged the services of an engineer, who made a thorough investigation, resulting in the decision to rebuild a wall across a narrow valley, advantage being taken of a gap in the hills, into which it was set as a wedge.

VIEW OF RIO GRANDE WORKS FROM NEW MEXICO SIDE, SHOWING CURIOUS ROCK FORMATION UTILIZED FOR AN ANCHORAGE OF THE MAIN CONCRETE DAM AND FOR SUPPORTING WALLS OF HEADGATES

The highest dam in America, according to the calculations of the reclamation engineers, will be the barrier now under construction in the State of Wyoming in connection with the Shoshone project. The Shoshone gorge, in which the work is being erected, is very narrow in proportion to its depth, the walls being of hard granite especially favourable for water storage. The dam will rise no less than 310 feet above its foundation; and so narrow is the canyon that the masonry will measure only 175 feet along its crest. Here, as at the Roosevelt dam, it was necessary to cut a road many miles in length out of the solid rock in order to gain access to the site. The dam will provide a reservoir with a storage capacity of 456,000 acre-feet, and by 1911 enough water will be available on over 100,000 acres of land. The dam will regulate the flow of the water, and 30 miles below the dam the stream will be turned into a tunnel three and a quarter miles in length, which will conduct it by a large canal into the district to be irrigated. This wall will be 13 feet higher than the



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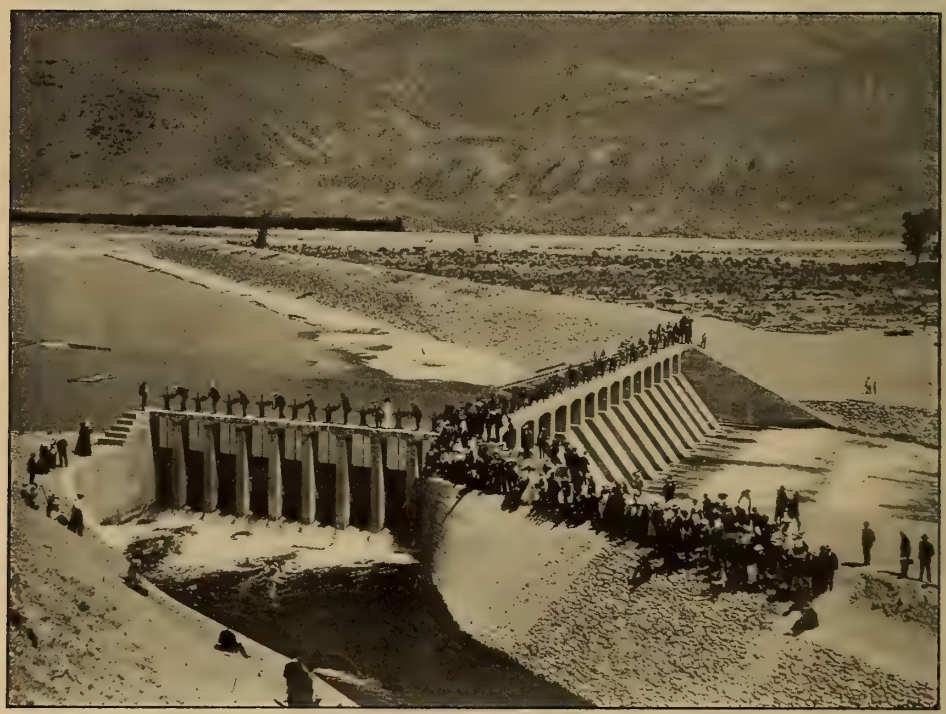
CONSTRUCTING THE SHOSHONE DAM, NEAR CODY, WYO.

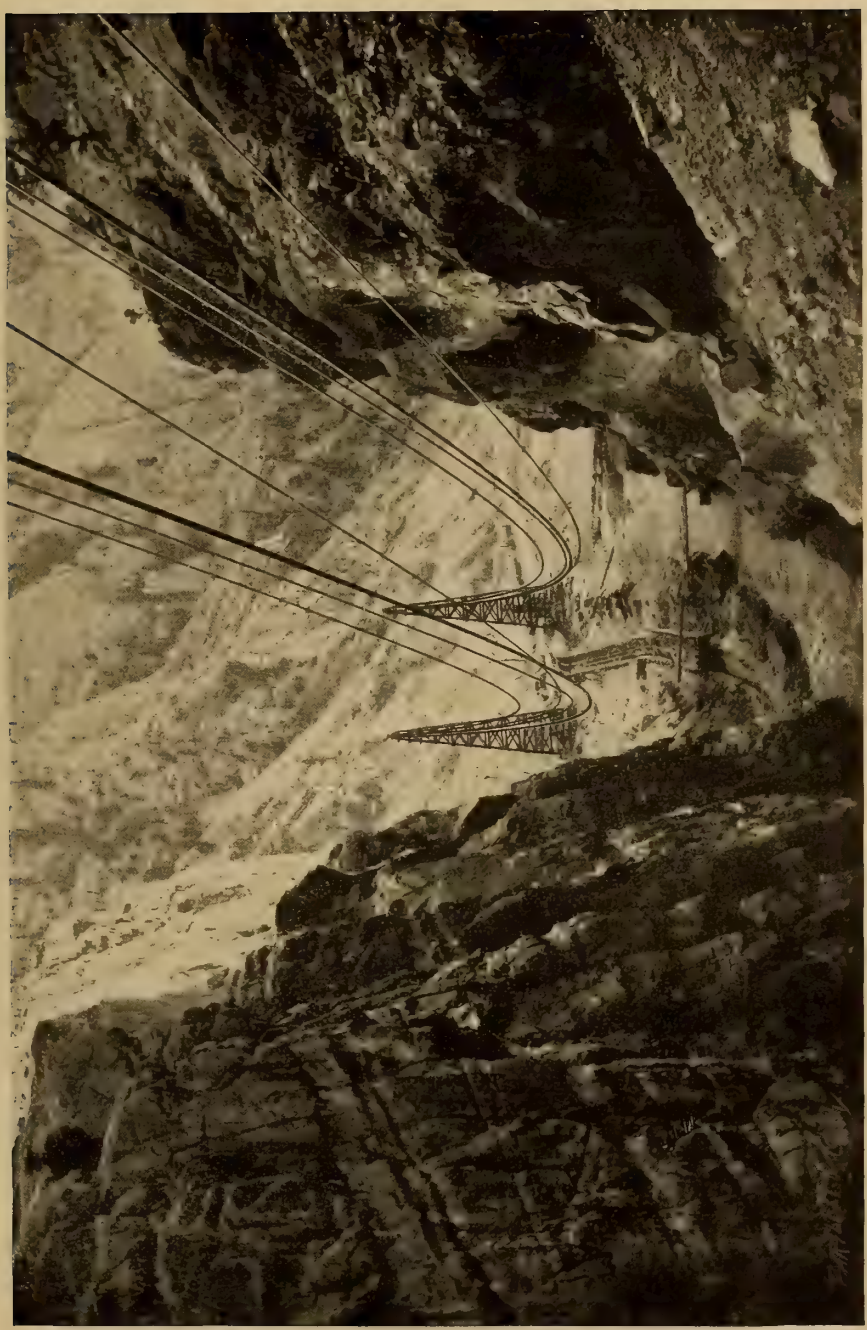
famous Croton dam which forms the Croton reservoir.

While the Rio Grande flows along a broad valley for a considerable distance in its course in the Southwest to the Gulf of Mexico, there is a point in New Mexico where the river channel is comparatively narrow, since it has apparently cut its way through a range of hills. Here another barrier is being created which will irrigate nearly 200,000 acres of arid territory which lie in New Mexico and Texas. Its greatest distance from top to bottom will be 255 feet, while in length it will exceed even the Roosevelt dam, being 1,150 feet from side to side of the hills referred to. By putting a barrier across this portion of the gorge of the Rio Grande, a body of water will be formed 40 miles in length, sufficient to flood 2,000,000 acres to a depth of at least one foot. The engineers have, however, not only pronounced this great scheme practicable, but have calculated that the dam and the network of canals which will extend from it into New Mexico and Texas will cost $5,500,000.

One of the most unique of the projects is known as the Truckee-Carson, from the fact that the Truckee and Carson Rivers have been controlled by a remarkable plan conceived by the engineers. These water courses have flowed into so-called "sinks," or sunken lakes, in Nevada. The flow of water, as shown by measurement, is adequate to serve an area of fully 300,000 acres. The problem for the engineers to solve was how to divert the water from the river channels and impound it in reservoirs of sufficient capacity. Several suitable reservoir sites have been found available at the headwaters of the rivers, and some of their feeders



THE RAISING AND LOWERING OF THE GATES AT THE NEWLY COMPLETED DIVERSION DAM AT THE HEAD OF THE MAIN TRUCKEE CANAL



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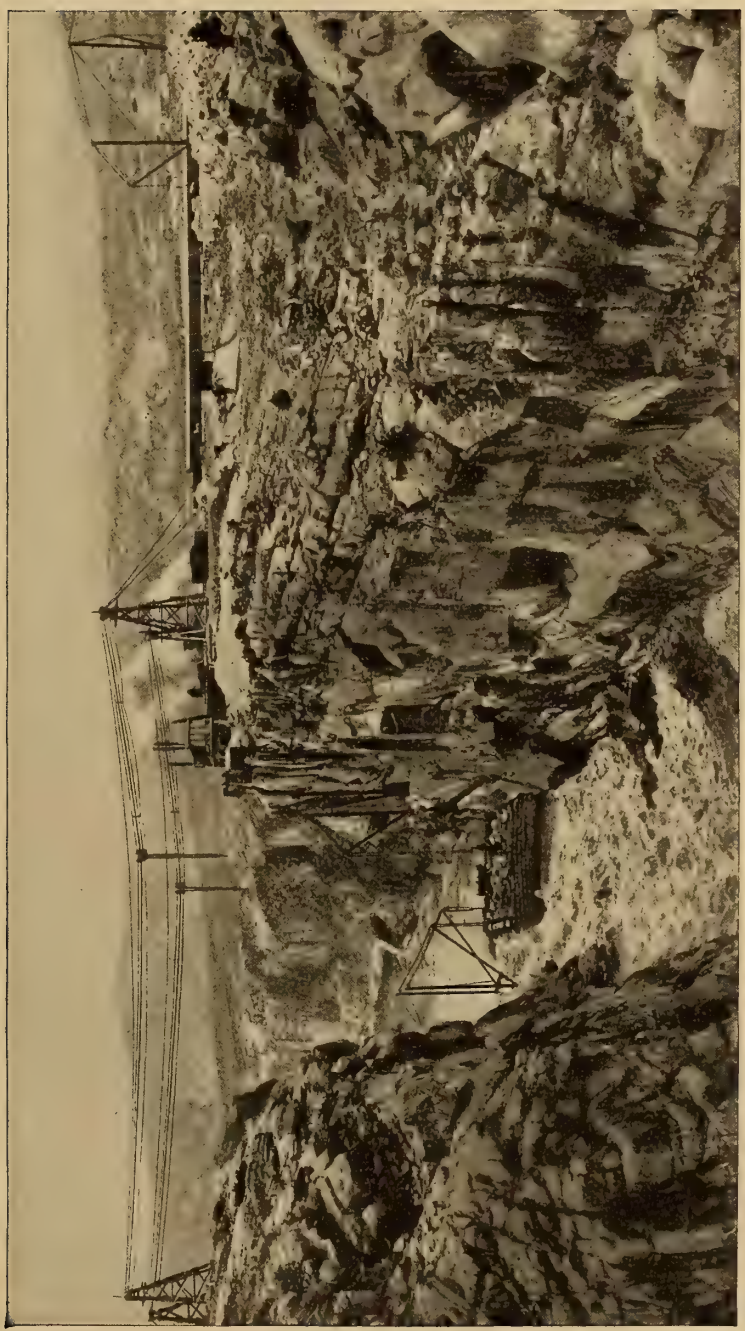
SITE OF SHOSHONE DAM, LOOKING UP STREAM INTO RESERVOIR

will fill these by excavating diversion channels. The most important feature of the plan already being carried out, however, is in connection with the Truckee River. The waters of the Truckee River are used for the irrigation of lands in the vicinity of the city of Reno. Below these lands the river flows through a narrow canyon and then turns to the north, its waters being lost in Pyramid and Winnemucca Lakes. In this lower canyon is being built a canal, taking out the flood and excess waters of the river which would otherwise be lost in the lakes, carrying them southeastward to a reservoir site on the lower part of the Carson River, in which, at the same time, the excess waters of the latter stream can also be used. From this reservoir distributing canals are being excavated to water several hundred thousand acres of land near Carson Sink. The plan involves some elaborate concrete construction, including the construction of highway bridges, falls, head-gates, culverts and spillways for the main distributing canals. The cost of the diversion canal will be about $1,100,000, while the branches will cost about half as much more.

A project which has been notable for its extent also—the construction of elevated canals or aqueducts to distribute the water—is the North Platte, intended for irrigating portions of Nebraska and Wyoming. The North Platte River in flood may rise over 20 feet above the low-water mark, as its watershed includes an extensive mountain area with a heavy snowfall in winter, which melts rapidly in the spring months. Careful estimates show that the volume of water is sufficient to fill a reservoir adequate to cover a million acres to the average depth of one foot. The dam forming this reservoir is among the highest included in the irrigation projects, and is connected with a distributing canal 95 miles in length. In several places this conduit consists, as stated, of aqueducts, some of which are over a mile in length, crossing valleys or other depressions in the surface. Here concrete is used entirely, and the aqueducts present notable examples of engineering work of this type. Within the next year the North Platte will be so far completed as to serve 110,000 acres of the States named.

The criticism may be made in connection with these works that the completed projects have not existed long enough to accurately determine their endurance and stability. While it is true that the reclamation service did not begin operations until the passage of the Conservation act in 1902, so many waterworks are now in service that they have had a fair test; but some of the older irrigating systems completed by private enterprise have proved beyond question that the engineers have been correct in their theory, and that their work is of a permanent character beyond question. Illustrations of this assertion are the Modesto and Turlock systems, in the State of California. They irrigate 250,000 acres in the districts named, the water being supplied from the LaGrange dam, already referred to. This dam cost $550,000, and is one of the highest overflow dams in the world. It is 127 feet high at its highest point, and has an average height of 97 feet. It is 301 feet long upon its crest. At its base it is 94 feet thick and at its crest 13 feet thick. The dam was built by excavating for a foundation and then building up a solid rubble masonry wall of rock, each rock weighing from 1 to 8 tons. It contains 40,000 cubic yards of this class of masonry, which was laid in 30,000 barrels of cement. The masonry was faced on both sides of the dam, and had a core of concrete laid in the centre to prevent possible seepage. The ground plan of the dam forms an inverted arch, the crown lying upstream. The upstream side of the dam is vertical, while the lower face has three slopes, varying from one-fourth to one. The dam was fin-



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HANDLING MATERIAL BY MEANS OF TWO CABLEWAYS IN CONSTRUCTING THE PATHFINDER DAM, NEAR PATHFINDER, WYO.

ished in 1893, and within three months after its completion it had 16 feet of water flowing over its crest. It has been put to an equally severe test many times since, but has stood the strain without showing a flaw or a weakness.

The Turlock canal is taken out on the south side of the river, 60 feet above the dam, and starts with a solid rock tunnel, 600 feet long and 12 by 15 feet in the open. The Modesto canal is taken out of the north side of the river just at the dam, and through an open rock cut, the carrying capacity of the Turlock canal being 1,500 cubic feet per second, and of the Modesto canal 640 cubic feet per second. For a distance of 22 miles each of these canals traverses the rough and broken country composing the foothills of the Sierra Nevadas before reaching the San Joaquin valley, where the distribution of water begins; and in this combined distance of 44 miles they present some as difficult problems in irrigation engineering as may be seen anywhere in the country. The more difficult work was encountered on the Turlock, which embraces not less than four rock tunnels and four principal flumes. The tunnels represent an aggregate length of 2,500 feet. The rock encountered in the first tunnel was of such a hard and flinty nature that three shifts of men working with drills were enabled to advance the work but 18 inches each twenty-four hours.

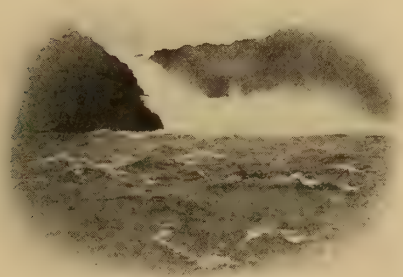
There are three flumes on high trestles on this upper portion of the main canal. The upper flume, which spans Morgan Ravine, is 300 feet long, and the bottom of the flume is 60 feet above the bed of the ravine. The second is that crossing what is known as Delaney Creek, and is 514 feet long and 61 feet above the bed of the creek. The third is that crossing Peaslee Ravine, and is 350 feet long and 64 feet above the ravine. Some 200 feet of the Delaney Creek flume collapsed during the season of 1904. The part damaged was immediately replaced with fluming of the same character, while the flumes across Morgan Ravine and Peaslee Ravine have been replaced with triple, inverted siphons of steel pipe 6 feet in diameter.

In a service of nearly twenty years the repairs necessary to be made to this California irrigating system has been the trifling amount of $75,000. The dam itself is to-day in good condition, despite the enormous pressure yearly exerted against it in the flood season.

Summing up the planning and building of the world's greatest waterworks, we are compelled to accord the engineer the credit for most of the success thus far attained. In this connection he can well be called the Quality Man. Irrigation has needed him as much as the mercantile enterprise the factory, the railroad and the bank. To these men of the United States reclamation service is due the credit for making the waste waters of the West of value, for they have not only studied the volume carried in the rivers and lakes and calculated the amount needed for the lands to be irrigated, located the sites and planned the dams, reservoirs and canals, but supervised the construction of every detail. In short, all of it has been so systematized that it is well worth study. While soil experts have analyzed the sand, clay and loam to find what would grow by the application of water, measurements have been taken by the engineers of the rain and snow fall and the other sources that feed the streams to be diverted to the arid lands. And while this has been in progress the men with the transit and sextant were scrambling up cliffs, wading and swimming rivers in the gorges, climbing to the summits of snow-clad peaks—all to make surveys of canal routes and storage sites. There were great valleys to be blocked with masonry and gaps made miles in length in the earth, the ground dug out and lined with concrete for hundreds of

miles; but here, again, were the Quality Men with electric and steam machinery to tunnel the hillside, to carry the building material, thus doing the work of thousands of men, under the guidance of their operators.

But what do the ability and effort of the Quality Men of the reclamation service mean to the nation at large?—what is there to it from the commercial standpoint? They mean increased demand in every product that is used in the home and on the farm. Stop and think of the factories and shops turning out home outfits, wearing apparel, farm machinery, wagons, carriages, twine, wire, fencing, the hundreds of miles of nurseries cultivating seed plants, tories and shops turning out home breeders who supply pedigree cattle, swine, draught and pleasure horses, the poultry farms raising high-grade fowls, to improve the grower's flocks. Here is a big market, a permanent market for every one of them and others. Each new settler means the purchase of so many necessities and a new customer. Perhaps he buys at the town store, from the "mail order" house in the big city, or from the "drummer." No matter how or where he makes his purchase, it is so much more business to the maker or grower, to the city merchant or to the village tradesman. Remember that since 1902 fully 25,000 farms have been taken up on the reclaimed land. This means one family to each farm, and five to a family is a small average. The settler must pay out for necessities at least $500 the first year—house and farm supplies, equipment and machinery. Multiply, and what do you have as one year's business? Over 12½ million dollars—money which goes not to a city, State or section, but which means revenue to producers and merchants throughout the United States; and this is only the beginning of a demand from year to year, and one that increases, for as fast as the "manless land" is reached by the waters the "landless man" comes to till it and to make it productive.



THE STABILITY OF SUBMARINES

By Bernard C. Laws, A. M. Inst. C. E.

THE submarine, unlike the ordinary vessel, with which we are more familiar, finds her sphere of activity essentially below the surface of the water. At times, however, it is necessary for her to show herself at least for a short period, in order to take bearings or otherwise to execute some necessary evolution. When not actively engaged she will, of course, remain moored at the surface in readiness to embark or discharge her crew and stores, or in preparation for further active service.

In considering the stability of the submarine, therefore, both the surface and the submerged conditions will have to be noted, and it is essential that the safety of the vessel be assured in respect of both the transverse and longitudinal direction.

It does not follow that a vessel which can be made to trim and steer correctly when floating at the surface of the water would necessarily show to advantage when submerged; not only are the conditions in the two cases different, but the factors upon which her safety depends are not quite the same in the one case as in the other.

For instance, any alteration in the distribution of the weights in the fore-and-aft direction, such as the movement of a member of the crew, or the addition or ejection of water ballast, though not altogether detrimental to the good behaviour of the vessel at the surface, might, in the submerged condition, so alter the longitudinal stability as to cause her to dip by the head or stern, as the case might be, and to steer erratically. If in such a case it were not possible to overcome such erratic tendencies, the vessel would be practically useless for warlike purposes, to say nothing of the danger to which she would be exposed, and with her the men on board.

The difficulties, however, have practically been overcome, and to-day a skillful commander can, with comparative ease and precision, carry out the work for which the vessel is designed.

In its inception, various fantastic forms of the submarine were introduced, culminating, it may be said, in the cigar shape, which latter eventually gave place to the fish form, with bluff nose and a transverse section practically circular, as exemplified in the Holland boat as we know it to-day (Fig. 1).

There has been no sudden transition of form, but, like most of the changes wrought in marine design, the development has been a comparatively slow process of trial and error, and after the expenditure of much labour, monetary outlay and loss of human life the present form has been evolved.

This type of vessel has to fulfil functions which are clearly outside the requirements of an ordinary vessel. Not only has she to perform work at the surface, but beneath it; she has to make her course with the compass for guide free from oscillation and retaining her stability.

To submerge a vessel is not difficult; but to do so and preserve a definite depth below the surface is a problem of a more difficult character, and one which may be said even now not to have been altogether satisfactorily solved.

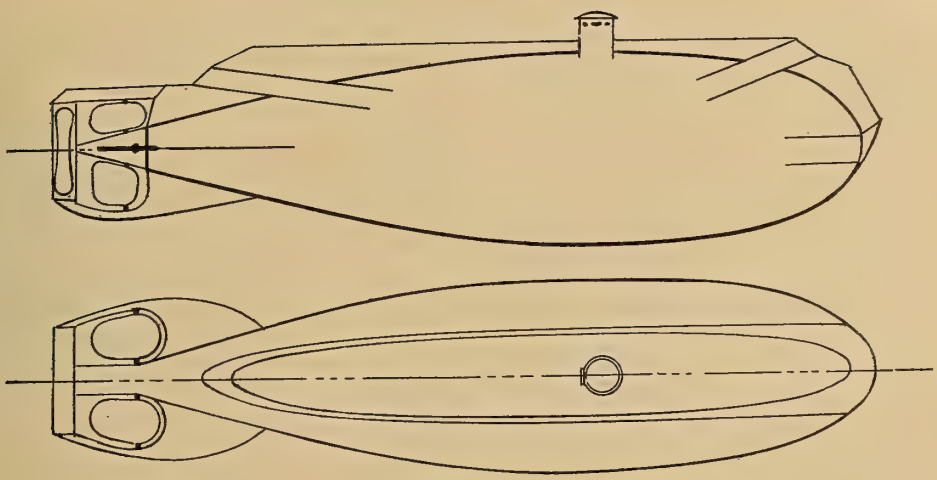


FIG. 1.—HOLLAND BOAT

The question of submersion naturally hinges on the relative values of the weight and buoyancy of the vessel, whether she be floating or suspended below the surface. Some of the methods employed may be noted.

In the case of the *Nautilus,* pistons working inwards or outwards in cylinders situated in the sides of the vessel were used to make the vessel sink or rise, as the case might be. In other cases vessels were fitted with portable weights or drop keels, which enabled them to sink, and which, when released, brought them quickly to the surface, often, as would be supposed, with not inconsiderable speed and with some degree of inconvenience to the human element on board and the probable loss of the released weights.

Some vessels have been designed with buoyancy *nil,* but no great amount of success has been realized with them. They are naturally very tender and sensitive to very slight disturbances—whether those disturbances be of the nature of wave motion or the movement of men or weights on board. Even small quantities of water finding ingress into ballast tanks, perhaps through the agency of leaky valves, would at once create a negative buoyancy and cause the vessel to sink lower and lower, thereby jeopardizing her safety. Conversely by the ejection of a small quantity of water a positive buoyancy would be established, causing or tending to cause the vessel to rise; so that such a vessel would be more or less continually in a state of vertical oscillation at once detrimental to its usefulness. Submarines now usually have a reserve buoyancy of a few hundred pounds, and the approved methods of obtaining trim, causing the vessel to sink or dive and preserving a definite required depth below the surface, consist in the use of water ballast on the one hand and the horizontal rudder on the other, while the vertical rudder is used for steering in the horizontal plane in a manner similar to that known in the case of ordinary vessels floating at the surface.

One other case of positive buoyancy may be mentioned in which vertical propellers; *i. e.,* propellers working on vertical shafting, were used to bring the vessel below the surface; the action of the propeller neutralizing the excess of buoyancy over weight. There was, however, the difficulty of preserving the exact desired depth similar to that experienced with the vessel of buoyancy

nil already described; the idea was either to reduce or increase the revolutions of the propellers according as the vessel was required to rise or sink, but the vertical oscillatory trouble was always apparent.

The horizontal rudder as the one means of submergence and of preserving the vessel in that condition on a steady course has become established, the boat is trimmed by means of water ballast tanks located at the extremities, and the change of draft from the light to that approaching the awash or diving condition is assisted by water ballast situated amidships. It is clearly seen that the centre of gravity of the vessel, complete and in diving condition, must be unalterable except in so far as it may be necessary to bring about a change at the will of the commander, as, for example, by firing a torpedo, the effect of which would be estimated beforehand and allowed for.

But in all cases the ballast tanks must be either *completely filled* or *completely emptied* in order to eliminate one possible source of danger, viz.: the presence of liquid free to move; by these precautions the precise position of the centre of gravity is calculable and for good stability is kept comparatively low.

In order to dive the vessel is propelled forward and the horizontal rudder is used to depress the nose or bow. Generally, under surface conditions, the bow may be assumed to be initially submerged, and if the vessel be started ahead there is an inherent tendency to dip by the head without the aid of the horizontal rudder, and with the broad-nosed modern boats this tendency is enhanced. Care, therefore, must be exercised in giving speed to a submarine when in this surface condition, because if a certain speed be exceeded she may be forced under, although the horizontal rudder has not been used, with possible dire results, should she happen not to be sealed. The boat will dip only on a certain speed being attained, as for less speeds the change of distribution of fluid pressure longitudinally consequent on that speed will not suffice to cause the bow to take the necessary depression. In the case of the Holland boat the minimum speed necessary to keep the vessel submerged is about five knots.

Hydroplanes or fins acting as adjuncts or auxiliaries to the horizontal

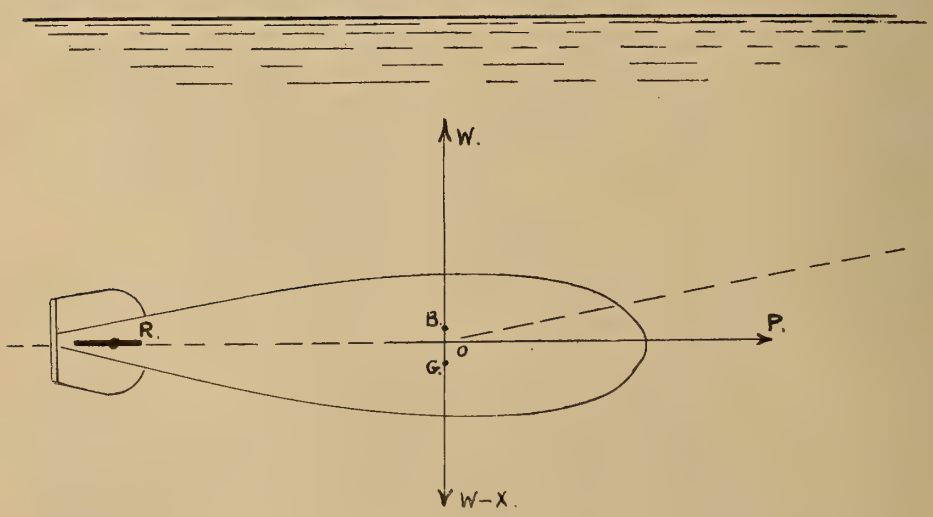


FIG. 2.—ILLUSTRATION OF BUOYANT FORCE ACTING ON SUBMARINE PROCEEDING UNDER WATER

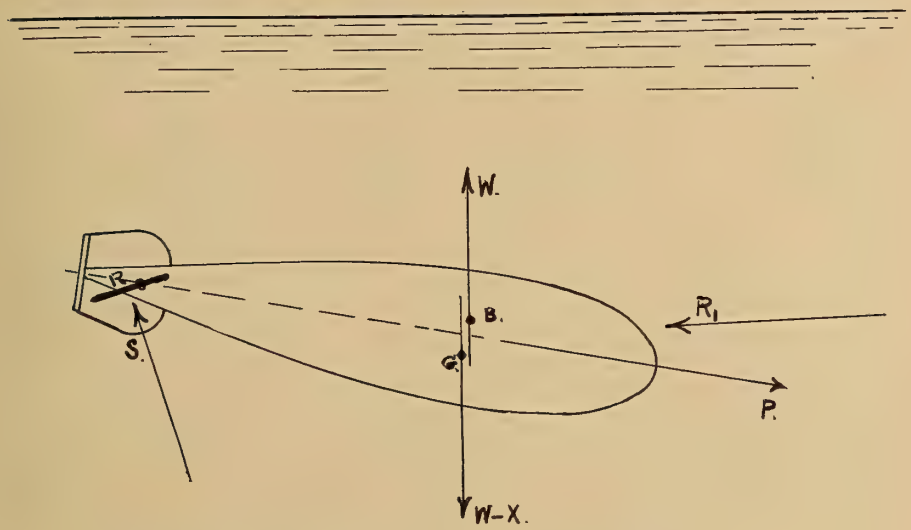


FIG. 3.—FORCES ACTING UPON A SUBMARINE PROPELLED HORIZONTALLY UNDER WATER

rudder have been introduced with good results and are placed symmetrically on the vessel. They have steadying qualities and assist the rudder in its action. One of their functions is to prevent the tendency of the vessel to dive when the horizontal rudder, which is situated right aft, is put down, which tendency is further augmented by the full form of the vessel forward upon which the fluid pressure acting tends to force the bow downwards; indeed, the forward hydroplanes are so placed as to experience an upward fluid pressure in order to counteract this downward tendency at the bows.

It is clear that the efficiency of the Holland and up-to-date type of submarine is obtained in quite a different way to that of the earlier types, inasmuch as the modern boat depends entirely on her rudders, the power of which in turn depends on the speed of the vessel; in consequence of this these boats have been well designated the dynamic type.

It seems almost paradoxical to assert that for a submerged submarine to proceed in a horizontal line or plane she must be propelled downwards. However, a little consideration will make it clear that if the boat, while proceeding below the surface, were placed on even keel and that condition retained, she would, ultimately reach the surface by a diagonal line like that ascending to the right from *O* in Fig. 2, which illustrates the vessel proceeding at a certain speed, with rudder *R* horizontal.

Suppose the propelling force to be *P* in the horizontal direction, there is also a vertical force *X*—equal to the difference between the weight and buoyancy of the vessel—acting upwards, which, combined with *P*, gives a resultant force in a direction inclined upwards and along which the boat tends to move. The opposing force is, of course, the fluid resistance, and upon the relative values of these two forces would depend the time taken to reach the surface.

Indeed, the motion would be similar to that of a projectile traveling through the atmosphere; and as in this case it would be necessary for the shot to have its virtual direction of motion inclined upwards in order that it may actually travel horizontally, so in the case of the submarine the virtual motion of the vessel must be downwards if she is actually to travel in a horizontal direction.

To do this, the rudder must be

put down, in which case the disposition of the forces acting on the vessel will be as indicated in the following Fig. 3, where:

P denotes the force propelling the boat;

R_1 denotes the final resistance to motion;

S denotes the fluid pressure on the rudder.

If we assume the vessel traveling in a horizontal direction, with uniform speed, we have:—The resolved part of P horizontally is equal to that of R and S in the same direction, and also the sum of the resolved parts of S, R and P in the vertical direction, together with W and $W—X$ is zero, and further the sum of the moments of all the forces about some horizontal transverse axis will be zero, for the condition that there is no rotation in a vertical plane; the position of the axis, about which the vessel will momentarily turn if the balance of the forces be suddenly disturbed, is difficult of calculation on account of the uncertainty of estimating the value and direction of all the acting forces. For this reason the adjustment of the rudder to suit any particular condition of running must almost necessarily be obtained by experiment or, tentatively, with the vessel herself, the helmsman knowing by the indications of a manometer in direct communication with the sea whether he is running at a certain required depth below the surface or is departing therefrom, in which latter case he must alter the angle of the horizontal rudder.

It is evident, then, that the form of the vessel has a considerable influence on the longitudinal stability, for upon this, for a given value of P, will depend the speed which, in its turn, will govern the value of S; and the value and direction of R will also be governed by it. On the other hand, though the form given to the boat naturally has an influence on the transverse stability, yet it is far less marked than in the case of longitudinal stability.

Generally the question of stability, whether of the one kind or the other, has to be considered very carefully for each of the specific conditions under which the boat will be required to work. Being essentially a diving boat, there must be a surplus buoyancy, so that, although the principal function is to act below, yet when occasion requires it she will float at the surface. In other words, she must be such that the

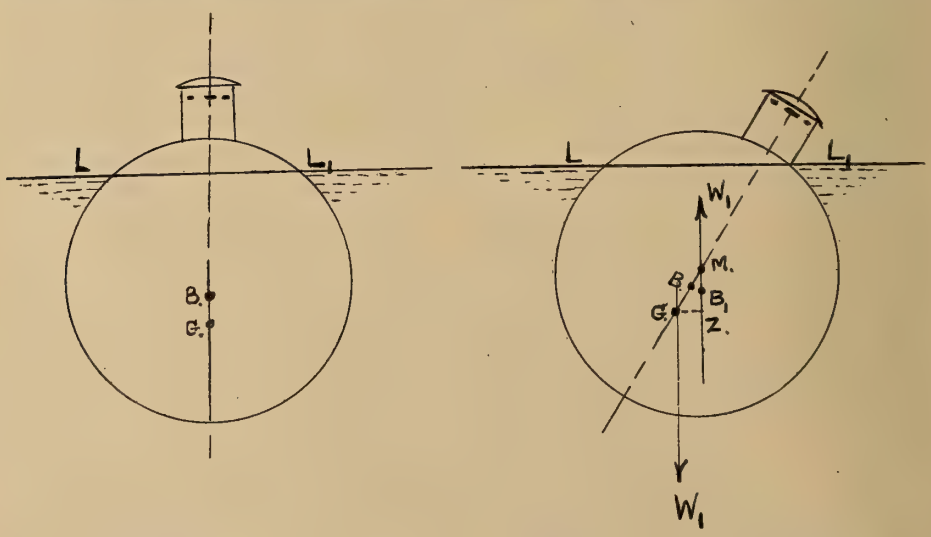


FIG. 4.—TRANSVERSE SECTION OF SUBMERGED SUBMARINE IN UPRIGHT AND LATERALLY INCLINED POSITIONS

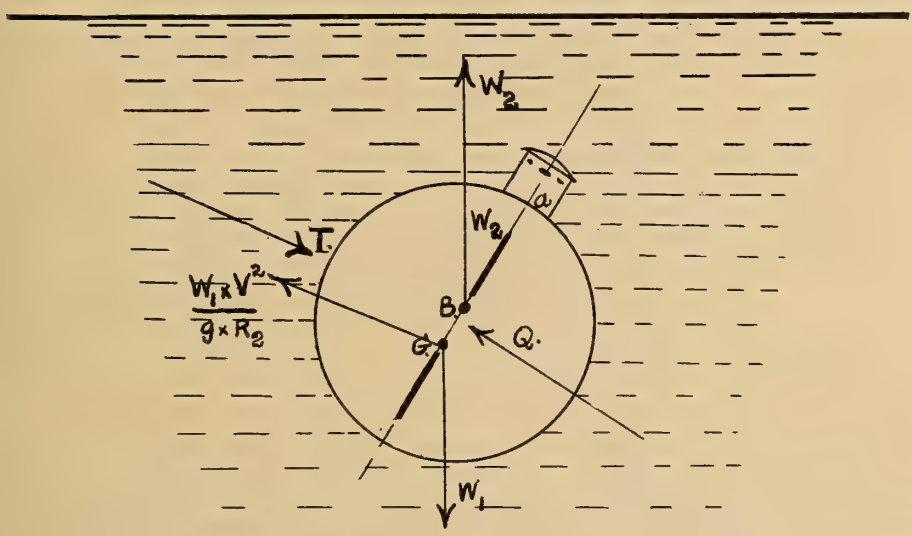


FIG. 5.—HEELING FORCES CALLED INTO EFFECT BY OPERATION OF THE RUDDER

total weight of hull machinery and equipment with all ballast and fuel tanks empty—termed the light condition—must be less than the weight of water of volume equal to that of the vessel; and not only so, but when fully manned, with tanks full, all stores, etc., on board and in fighting condition, she must still have a certain amount of reserve buoyancy sufficient to allow her to be sealed up before diving with a portion of the hull above water. This is the diving condition, and is such that there is generally a margin of a few hundred pounds reserve buoyancy.

There are, therefore, three principal conditions requiring special attention, two of which refer to flotation, viz.: the light and diving conditions and the third to submergence, this latter only differing from the diving condition in so far as it is brought into being by the action of the propeller and the horizontal rudder. When floating with any portion of the upper works exposed, as in the first two conditions cited above, the submarine is subject to the same laws as regards flotation and stability as the ordinary vessel, and even when submerged there is a similarity of treatment with regard to transverse stability.

The illustrations shown in Fig. 4 may be taken to represent the transverse section of a submarine—not necessarily circular, LL_1 being the waterline, G and B_1 the centres of gravity and buoyancy respectively in the same vertical line when the boat is at rest. If the vessel momentarily heel from the upright, the position of B will change to B, and the vertical line through B will intersect $G\ B$ in the point M—the metacentre; the righting couple tending to restore equilibrium is $W_1\ x\ GZ$ where $G\ Z$ is the perpendicular drawn from G on to $B_1\ M$.

These are fundamental theoretical principles which apply to all types of floating bodies, but in the present case there is this difference that, whereas the water plane area in one —the diving—condition is reduced to a minimum, usually very little more than the sectional area of the

FIG. 6.—WAVE LINE SHOWING PATH OF SUBMARINE PROCEEDING UNDER WATER

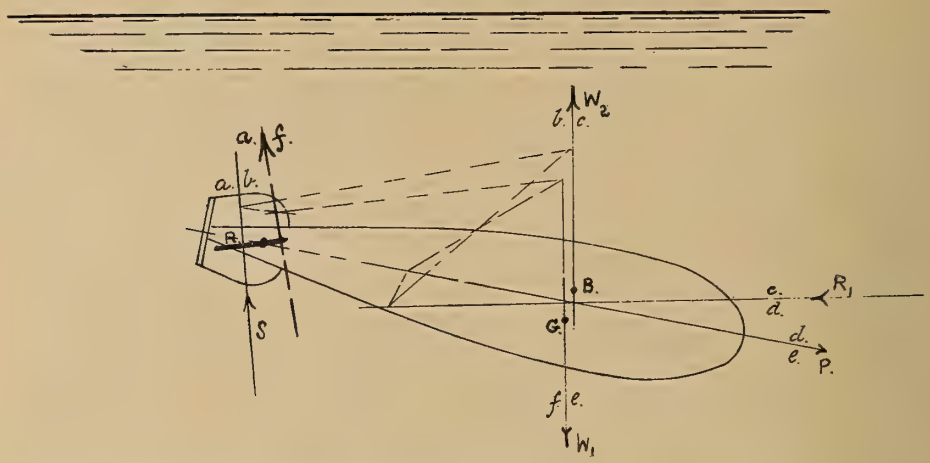


FIG. 7.—DISPOSITION OF FORCES ABOUT SUBMARINE AFTER DISTURBING ITS VERTICAL EQUILIBRIUM

conning tower, the water plane area in the case of the ordinary vessel is considerable.

From this consideration it will be seen that the value of $B\ M$, which is equal to:

$$\frac{\text{Transverse moment of inertia of water plane area}}{\text{Volume of displacement,}}$$

is never large—except in the light condition, and in the diving condition is very nearly zero, which latter is the value assumed when the vessel is actually submerged, so that the metacentre M and the centre of buoyancy B are then coincident whatever the angle of inclination of the vessel. But the power to right herself is not now—*i. e.*, for the submerged condition—a simple couple; $W_1, x\ G\ Z$, as is sometimes stated, or $W_1, x\ G\ B\ Sin\ \theta$ where θ is the angle of the heel and W_1, the weight of the vessel, and for the sufficient reason that the weight of vessel is less than the weight—W_2 say—of water displaced. The righting power resolves itself into the couple $W_2\ x\ G\ B\ Sin\ \theta$, together with a force $W_2—W_1$, acting vertically upwards at G, which latter has the tendency to bring the vessel to the surface. This tendency, as has already been explained, is counteracted by the action of the horizontal rudder while the vessel is underweigh, but is realized as soon as the propelling machinery is slowed down or stopped.

A few remarks will now be offered as regards the action of the ordinary (vertical) rudder on the steadiness and stability of the submarine.

In an ordinary vessel it is not usual, except in specific cases, to consider the heeling effect of the ordinary or vertical rudder, but in the case of the submarine it forms a not unimportant matter for consideration, and with it the position of the axis, about which the turning takes place, assumes some importance, since the sum of the moments of all the acting forces about this axis is the statical stability of the vessel in the transverse direction.

When the rudder is put over, the distribution of the force action will be that shown in the Fig. 5, where Q is the fluid pressure on the rudder

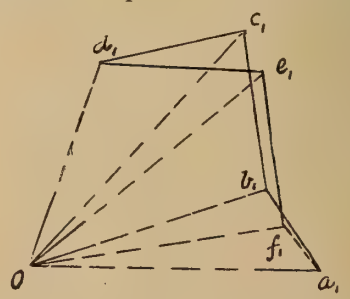


FIG. 8.—DIAGRAM OF FORCES DETERMINING STABILITY OF SUBMARINE

resolved perpendicular to the plane *A B G*; *T* is the fluid resistance to centrifugal action,

$$\frac{W_1 \times V^2}{G \times R_2}$$

is the centripetal force, on the assumption that the vessel moves at a speed *V* in a curved path, the radius of curvature of which is R_2 at the particular point and instant considered; these forces, together with W_1 and W_2, all act together to influence the heeling of the vessel as she turns out of the straight path, and their effectiveness will depend on the position of the axis about which the heeling takes place.

It may be assumed without much consideration that this axis will be in or near the plane *A B G*, but its particular position, say relative to *"a,"* will be governed by the values of the variable quantities *Q*, *V* and *T*, and for any specific case would require to be estimated.

It has been demonstrated that there is an intimate association between the longitudinal stability and form of the submarine.

The blunt nose and fine after end is now practically accepted as giving the vessel good steering qualities, favouring speed and minimizing oscillation, points all of which are most essential in the case of a vessel which has such unique functions to perform, and the absence of which might easily spell disaster not only to the vessel herself but to those other units with which she may be co-operating. This is at once apparent when we consider that small variations of steering in the vertical direction are likely to bring the vessel nearer to or take her farther from the surface than is necessary for the carrying out of the specific project in hand, whereas even a small amount of oscillation would at least be likely to bring about inaccuracy of aim in firing a projectile. By careful manipulation of the steering mechanism the oscillation may be reduced to a minimum and the vessel kept on her course, not perhaps in a straight line, but in a path which partakes more or less of a wave form, as shown in Fig. 6, in which the amplitude is small compared with the length, the mean straight path being preserved.

If from some cause the bow were impulsively lifted or depressed, the equilibrium of the vessel would be immediately disturbed, accompanied by a tendency to rotate, which would cause her to rise or dive as the case might be. The nature of the force action would be similar to that indicated in Fig. 7, in which the disposition of the forces is the same as that shown in Fig. 3, except that now *S* includes the extra pressure on the rudder, due to putting the latter further down.

Constructing a diagram of forces (Fig. 8), we obtain *"af,"* the resultant force acting on the vessel. Taking the pole *O* and constructing the funicular polygon in Fig. 7, we obtain the situation of this force; *i. e.*, *"af,"* which, assuming for the moment the axis of rotation to be somewhere in the vicinity of *G*, would tend to make the vessel dive; this tendency, measured by the moment of *"af"* about the axis, is really the longitudinal stability under this condition and is negative.

By raising the rudder and so bringing the nose upward there is a tendency to the restoration of equilibrium.

The position of the axis about which the vessel tends to turn, whether that movement be either in the longitudinal or transverse direction, is of importance. It is not fixed, nor is it, as has been stated by some writers, necessarily situated at the centre of gravity of the vessel. It will naturally depend, amongst other factors, upon the magnitude of the disturbing force and the position of that force in any specific case.

ELECTRIC TRACTION ON THE CONTINENT

By A. J. Thompson

In the Railway Number of this magazine, published last month, there appeared a general discussion of the electric locomotive, by Mr. Theodore Rich, and the present article may be considered as a supplement to that paper in that it describes certain special installations of electric traction in Switzerland, Germany and other parts of the Continent. Some of the locomotives mentioned by Mr. Thompson will be found illustrated in the paper of Mr. Rich, and the two articles will be seen to combine to cover the subject very completely so far as recent work in this line is concerned.—The Editor.

ALTHOUGH some of the most important developments in the application of electric traction to railway service appear in the conversion of portions of former steam railways to electric power, notably in the entrance to terminals in large cities, some important work is being done, especially on the Continent of Europe, in original construction.

A noteworthy undertaking of this kind appears in the new railway which is under construction across the Alpine region of the Bernese Oberland, in Switzerland. This road is interesting for several reasons, and especially because it contains the great Loetschberg tunnel, the most extensive piece of tunneling carried on in Europe since the completion of the Simplon tunnel. In fact, the Loetschberg tunnel may well be compared to the Simplon in magnitude. The railway and tunnel are to cost $15,000,000, although the entire system has a length of only thirty-five miles. Apart from the tunnel the road is of interest, because it is to be operated exclusively by electricity. This is the first instance on the Continent of the construction of a standard gauge railway designed originally as an electric system, as practically all existing standard-gauge electric roads have been changed over from steam railroad lines.

The enterprise is controlled by the Bernese Alps Railroad Company, and the railway is expected to have a material influence upon the international traffic passing through Switzerland, as it connects the north and south railroads by a more direct route. In fact, it provides a direct route from the important railroad centre of Berne to Simplon tunnel, passing across the chain of the Oberland and affording connection thence to the railways of northern Italy which centre at Milan. Thus trains, coming from the north of Europe and reaching Berne, will no longer be obliged to make a long detour to pass around the Oberland range, since the new railroad will constitute a direct connection between Berne and the Simplon.

The railroad has a length of 8.7 miles on the northern side of the tunnel, and extends 17.6 miles to the south of it, while the tunnel itself is 8.5 miles long, giving the total length of the Oberland railways as 34.8 miles. The northern section follows a winding route to the picturesque valley of the Kander, reaching the mouth of the tunnel at Kandersteg, a point 4,000 feet above sea level, where a large power plant is constructed. The tunnel pierces the mountain on a level grade and emerges in the precipitous valley of the Lonza, an affluent of the Rhone. The route then descends the valleys of the Lonza and the Rhone, reaching the entrance of the Simplon tunnel at Brigue. The electric trains here make connection with the Simplon route, passing through the

Simplon tunnel to Iselle, whence the trains are to be taken over the Italian railways by steam locomotives.

The writer recently had the opportunity of inspecting the work upon the south end of the tunnel, at Goppenstein, which is situated in a wild and inaccessible region of the high mountains. A prosperous town has been developed here since the work on the tunnel was started, and the place is a scene of great activity. Many important workshops and storehouses are situated here, together with an air-compressor plant, storage for cement, stone and other materials.

SOUTH END OF THE LOETSCHBERG TUNNEL AT GOPPENSTEIN

The tunnel itself is of the double-track, circular-arch type, and is 26 feet wide by 20 feet high, provided with a 20-inch masonry lining throughout. The rock drills are at work continuously, the power being derived from two hydro-electric plants upon the Lonza, the air compressors and other machinery being driven by electric motors. The trains are to be operated by electric locomotives of 1,500 horse-power, and the Bernese Oberland Railroad Company has already expended $200,000 in equipping a section of the road, in order to conduct experiments upon several types of electric locomotives and to obtain practical operating data. A single-phase current of 15,000 volts is to be used.

The general appearance of the southern end of the tunnel is shown in the illustration. This region is surrounded by the lofty peaks of the Bernese Oberland, among which the Balmhorn may be seen on the left, as well as other high peaks, partially covered with glaciers, in the vicinity of the Jungfrau; these mountain peaks include some of the highest in this part of Switzerland.

Coming now to the Simplon railway, several new features are to be noted, such, for example, as the new type of electric locomotive, constructed by Messrs. Brown, Boveri &

SOUTH ENTRANCE OF THE LOETSCHBERG TUNNEL DURING CONSTRUCTION

Co., the builders of the earlier machines. The older type of locomotives, some of which are still in use, have three main driving axles, situated in the middle, with a supporting axle at each end having wheels of much smaller diameter, thus making five wheels on a side. In the newer locomotives the small wheels have been omitted, and there are four driving wheels on each side. There are two electric motors of 700 horse-power each, placed side by side in the middle of the machine and operating with a three-phase current at 3,000 volts. The crank of each motor operates a connecting rod, which is connected to cranks on each of the four wheels, so that all four wheels are driven by the combined action of the two motors. Several innovations have been introduced by Messrs. Brown, Boveri & Co. in the design of these 700 horse-power motors, including a squirrel-cage armature made of heavy copper bars. Another feature is the absence of external resistances, while in each of the sloping ends of the locomotive there is carried a large transformer, one being for each motor. A pneumatic controller is so arranged as to enable the connections to be varied at different points upon the transformer coils, and thus regulate the power and speed. The speed may also be varied by changing the pole connections of the motors; all of these devices being operated by pneumatic switches within immediate control of the motor man.

The present trains through the Simplon tunnel between Brigue, on the Swiss end, to Iselle, at the Italian terminal, consist of one electric locomotive, and from ten to twenty standard passenger cars. The trains of the Swiss railway are stopped at Brigue, and the steam locomotives replaced by the electric machines, an operation which requires but a few minutes, and the cars are hauled through the

tunnel, a distance of about twelve miles, at a speed of about forty miles an hour. After coming out of the tunnel, the electric locomotives are again replaced by steam engines and the train proceeds on to Milan. The electric current is supplied from overhead conductors.

The electricity is furnished by power stations at Brigue and at Iselle. At Brigue there is an alternator of 1,200 horse-power, driven by a turbine taking its power from the Rhone, while at Iselle the water power comes from the Diveria. A recent addition at Brigue is the electric-lighting stations, which are shown in the illustrations.

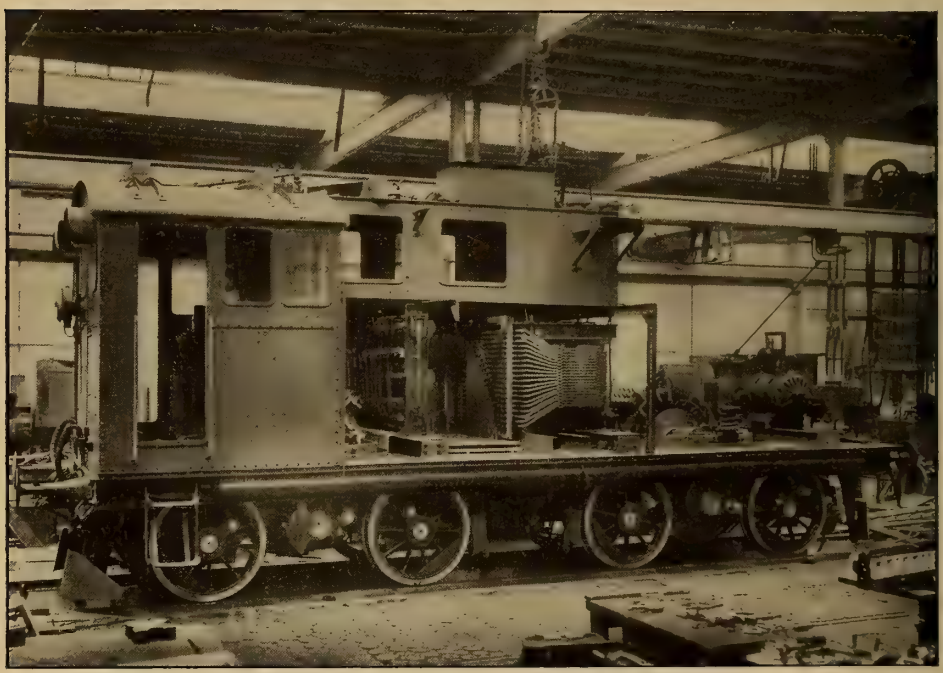
This plant contains two principal groups of alternators, supplying current both for lighting the stations and yards, and also the lamps within the tunnel. Signal lights are placed at each kilometre in the tunnel, and these are lighted while a train is passing through. The block signal system is operated from a station in the middle of the tunnel, this being provided with a storage-battery system, controlling signals and bells, and being in communication with a number of telephone stations spaced along the tunnel.

The great depth of the tunnel beneath the summit causes the temperature to be high, and if it were not for the powerful circulation of air which is maintained, the twenty-minute passage would be very uncomfortable for the passengers. A large blower system has been installed at each end of the tunnel, and the forced circulation keeps the temperature of the air down, but even under these circumstances the warmth of the atmosphere is very perceptible.

Several years ago a proposition was made by the Oerlikon Company to equip the railway line running between Seebach and Wettingen, in the Zürich district, with electric traction, using a heavy electric locomotive to haul the trains. This section is now electrified throughout, and forms a portion of the Swiss

NORTH END OF THE SIMPLON TUNNEL NEAR BRIGUE

Federal Railway System. The line forms an excellent example of the application of single-phase, high-tension current to railway operation, using overhead trolleys and a current of 15,000 volts. A portion of this line is equipped by the Siemens-Schuckert Company, who furnished one of the locomotives, as it was desired to make an operative comparison between the two systems. consisting of a single-phase motor and direct-current dynamo. The motors of the locomotive, of 200 horse-power each, were thus supplied with direct current. The second machine was arranged to use alternating-current motors, and its success was such that it was decided to change the first machine to the same plan. This second locomotive weighed 46 tons, and was provided

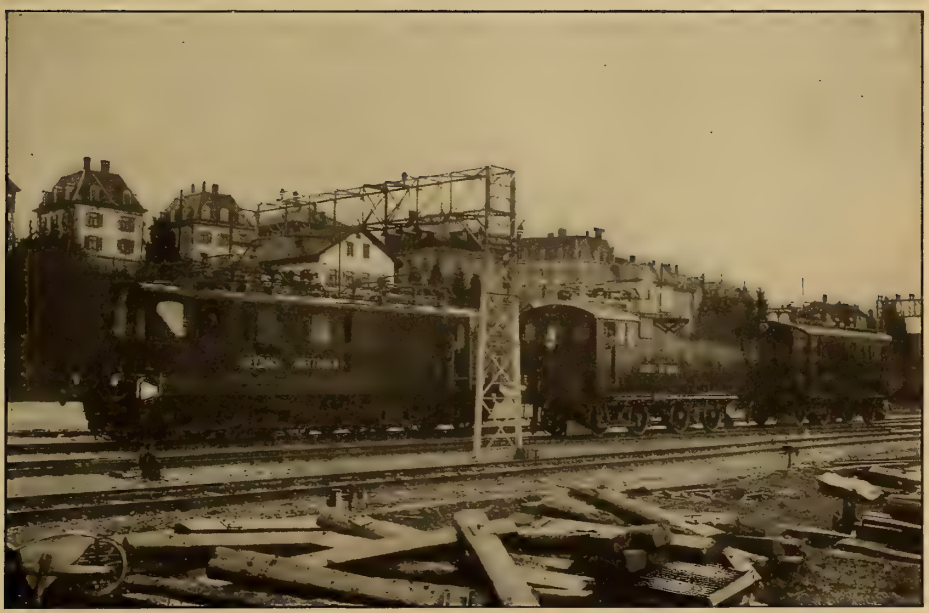


CONVERSION OF THE OERLIKON LOCOMOTIVE NO. 1 FROM DIRECT-CURRENT TO ALTERNATING-CURRENT SYSTEM

The use of the high voltage made it necessary to use great care in installing the overhead system. The locomotives are of various sizes, the heaviest developing 900 horse-power. A special form of trolley is employed on the Oerlikon machine, adaptable to the position of the overhead wire, which sometimes runs at the side of the locomotive, and sometimes over the middle of the track.

The first locomotive was arranged to carry a converter group, the current being first lowered to 700 volts, and then passed to a rotary converter with a controlling cabin at each end, and was mounted upon a double-bogie truck, with one 250 horse-power motor placed between the axles of each bogie. The locomotive was provided with an Oerlikon type trolley, and also a bow trolley, the latter for use on the portion of the line equipped with the Siemens-Schuckert system. The lightning arresters and apparatus are also placed on the roof, especial care having been taken to protect the machine and line against atmospheric discharges. The high-tension wire from the trolley enters the locomotive and

LOCOMOTIVE NO. 2 ON THE SEEBACH-WETTINGEN LINE, BUILT BY THE OERLIKON COMPANY



HEAVY LOCOMOTIVE AND TRAIN OF THE SEEBACH-WETTINGEN RAILWAY, USING HIGH-TENSION ELECTRIC CURRENT

passes to two transformers, by which the tension is lowered from 15,000 to 700 volts. These transformers are placed in the middle of the machine and are cooled by a strong draught of air. These locomotives attain a speed of forty miles an hour, hauling trains of 270 tons up gradients ranging from 0.8 to 1 per cent., and in a few instances reaching 1.2 per cent.

The third type of locomotive, built

tors to be changed. The secondary circuits are controlled by means of a series of electro-magnetic relays, which act to connect one or more of the secondary windings of the transformer to the motors, giving a series of combinations for speed-changing. These relays are operated by a controller drum in the motorman's cabin by means of a hand wheel. As now provided with four motors, this locomotive weighs 7.5 tons, and when

NEW TYPE OF LOCOMOTIVE BUILT BY GANZ & CO., OF BUDAPEST, FOR THE VALTELLINA RAILROAD

by the Siemens-Schuckert Works in Germany, is of a quite different type. It is provided at present with four motors, but is so designed that six motors may be employed if it is desired later to increase the power. Two bogies, of three axles each, are used in the present case, and there are two motors for each bogie. The two kinds of trolleys are mounted on the roof, as in the previous machines. Two transformers of 500 kilowatts each are placed near the middle of the locomotive, these having the secondary divided into three parts, so as to enable the voltage upon the motors to be changed. The secondary circuits are controlled by means of a series of electro-magnetic relays, which act to connect one or more of the secondary windings of the transformer to the motors, giving a series of combinations for speed-changing. These relays are operated by a controller drum in the motorman's cabin by means of a hand wheel. As now provided with four motors, this locomotive weighs 7.5 tons, and when fitted with six motors its weight will be 8.3 tons.

This Seebach-Wettingen line has been in operation for some time with regular passenger traffic, and in it all the problems connected with electric traction upon standard gauge railway service appear to have been met. No difficulty has been encountered in the use of the high-tension current upon the overhead line, notwithstanding the local disadvantages involved in dampness, dust, and smoke caused by the operation of steam locomotives upon the adjoining freight tracks. Judging from the present

MOTOR BY GANZ & CO. USED ON VALTELLINA ROAD

results, the next step of constructing electric locomotives of 3,500 to 4,000 horse-power will be entirely practicable.

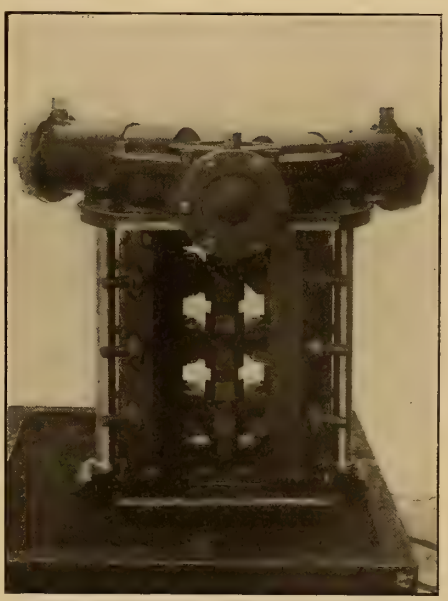
Electric locomotives are used on the Valtellina Railway, in Italy, this being under State control, and one of these machines is illustrated. These locomotives are built by Ganz & Co., of Budapest, and are an improvement on the machines formerly built by the same firm.

In their mechanical features these resemble somewhat the locomotives built for the Simplon, which are now running in the tunnel section, together with the new ones of the Brown-Boveri type mentioned above. There have been many changes, however, as regards the electrical features. The new locomotives are provided with two motors, one having eight poles and the other twelve poles. Both of these use high-tension, three-phase current at 3,00 volts and 15 cycles. When either motor is used alone the two high speeds are given, while by coupling the motors in series a third speed is obtained. The motors are connected electrically according to the system of Koloman von Kando, and give speeds of 40, 25 and 15 miles an hour. The normal tractive power is 7,700 pounds, or at the slow speed 13,200 pounds. The test requirement was that such a performance was to be conducted for ten hours, during which the temperature of the motors should not rise above 60 degrees centigrade. These tests have been made successfully and, in fact, the motors can be pushed still higher.

On a one-hour test the 8-pole motor gave 1,500 horse-power, with a 75-degree temperature rise, and the 12-pole motor furnished 1,200 horse-power.

An interesting detail about the motor is that it is not built of cast steel, but of laminated iron and forged pieces assembled. The weight of the 8-pole motor is 14.7 tons, and that of the 12-pole motor 13.6 tons. A double pantagraph trolley is used, and together with the switching and controlling device it is operated by pneumatic control.

While aerial cableways, with suspended cars, are in use for carrying material of various kinds, using spans of 1,500 to 2,500 feet, a passenger system of this sort is somewhat of a novelty. The first instance of the kind is the new cableway erected on the slope of the Wetterhorn, Switzer-



PNEUMATIC MOTOR CONTROLLER FOR GANZ LOCOMOTIVE

WETTERHORN CABLEWAY CAR LANDING AT TOP STATION, 4,135 FEET ABOVE SEA LEVEL

land, and it has proved all that could be desired. Tourists are thus taken up to an elevated point on the mountain side, whence they can continue the ascent of this celebrated mountain, whose peak lies at an altitude of 12,240 feet. M. Feldman designed the aerial cableway now in use, he being one of the leading promotors of the Elberfeld-Barmen suspended railway. The line starts from an already elevated point lying near the well-known excursion centre of Grindelwald, and the lower station is situated at an altitude of 4,135 feet, while the top station is 5,537 feet high, making the perpendicular distance 1,402 feet. The span of the cableway is about 2,000 feet. In the upper station are the electric motor and the mechanism for operating the cable drum.

This undertaking was carried out by one of the leading Swiss firms, the Von Roll Foundry & Machine Works at Berne. This concern makes a specialty of cable-road construction, having now more than fifty such plants installed in various parts of Europe, in Switzerland, Italy, France and other countries. The electrical outfit of the Wetterhorn plant was installed by Brown, Boveri & Co., of Baden; it included the principal motor, with controller and other apparatus, and also a rotary converter and storage battery. The motor is operated by direct-current of 800 volts tension.

The present system uses a traveling carriage, which runs upon a set of four sheaves or rollers upon a double-stretched cable. The double cable thus forms the track, and there is one such cableway for the ascending car, and another lying parallel to it for the descending one. From the carriage, the small car containing the passengers is suspended. In order to propel the carriage upon the cableway a double-traction cable is attached to the forward end of the carriage. At the upper station there is a set of cable drums driven by gearing from an electric motor, upon which are wound the cables of

VIEW OF CAR SUSPENDED FROM CABLEWAY

the ascending and descending cars, as in the case of an ordinary cable incline, one car descending while the other rises, so that the descending car helps in the propulsion of the rising one.

One illustration shows the method of suspending the passenger car from the rolling carriage, and also the position of the upper and lower carrying cables. The carriage is of light design and is provided with two rollers at the top and bottom for traveling upon the stretched cables of the incline. At the forward end of the carriage is a cross-arm upon which is fixed one of the tractive cables at each end. The two steel cables of the cableway are 1.8 inches in diameter and weigh 22 pounds per yeard. They are capable of sustaining a load of 150 tons, as was shown upon tests, and therefore they have a high factor of safety, such as is necessary in structures of this kind; since that the actual load is not more than 14 tons. The traction cables are of 1.2 inch diameter and have a like margin of safety.

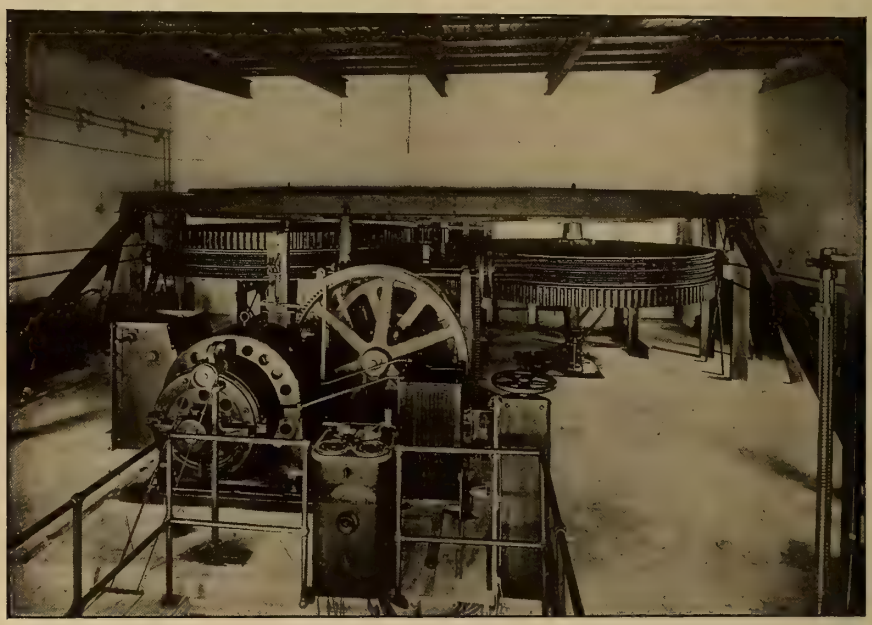
From the rolling car is suspended the passenger car, containing eight seats and the same number of standing places. It was found necessary to leave a space in the middle of the car, in order to allow the cables to pass down through it where the cableway lies on a very steep gradient. In this case the rolling carriage is greatly inclined, and, when in this position, the body of the car would touch upon the cables were there not left a space in the car body. The car has a platform at one end, which comes against the landing platform of the stations at the upper and lower ends of the course. An iron ladder leads from the platforms to the roof of the car, so that an employee can mount up to a level with the rolling carriage and can examine it at any time. The suspended car is 10 feet 6 inches long and 11 feet 2 inches wide. It is provided with very efficient brakes, which are applied against the carrying cables by means of strong springs.

CAR TRAVELING ALONG THE WETTERHORN CABLE-WAY. THE CAR IS SEEN AS A GREY POINT IN THE CENTRE

The current for operating the cable drums is supplied from an alternating-current electric plant situated near Grindelwald, and is brought at 2,400 volts to the lower station of the cableway, where a rotary converter group for furnishing direct-current for the cable-drum motor of the upper plant is installed. By using a storage battery upon the motor line a good reserve is provided in case of failure of the current. The upper station contains the cable drum with the 50-horse-power motor and the various driving appliances. The motor receives current from the pole line, which passes up the side of the slope from the lower plant. Means are provided for operating the cable drum by hand if necessary, using a hand drum of small size, so that the car can be brought to the end of its course at a slow speed. A small rescue car can be let down upon the rope way in case the main car should get blocked on its way, in order to afford aid in releasing the car or to take off the passengers if necessary.

All the various points have been carefully considered, so as to avoid mishaps of any kind, especially because this cableway is a new enterprise in this direction.

One of the interesting features in the development of electric mountain railroads in Switzerland is the recent extension of the line passing through the Mont Blanc region, to make connection with a new electric railroad line. In this way, tourists are able to pass completely through the valley which lies at the base of the Mont Blanc range. Heretofore, a part of this attractive region was quite difficult of access, on account of a lack of railroad facilities, and it is now expected that by the united operation of the Fayet-St. Gervais-Chamonix line on French territory, and the new Martigny-Chatelard line upon the Swiss side, tourist traffic through this region will be greatly increased. Formerly the electric railroad ended at Chamonix. This latter point was reached by first taking the steam railway at Geneva, and then connecting with the Fayet-Chamonix line at Fayet, whence the electric line passed up the picturesque valley of the Arve. After a time, Mont Blanc comes in sight, and from this moment on the ride continues to be a very pleasant one. Chamonix is reached after a trip of 11 miles. On this part of the electric line there are seven long viaducts, the largest of which is the Sainte-Marie Viaduct, having a central arch of 80 feet span and seven other arches, and being 170 feet high above the Arve. There are also three tunnels on the line.



POWER STATION OF THE WETTERHORN CABLEWAY, SHOWING MOTOR AND CABLEDRUMS

The electric trains are made up of a series of motor cars of about the same size. Each of the cars is equipped with two electric motors of 60 horse-power each. The front car differs from the others in having the controlling apparatus, devised by the Engineer Auvert, which serves to operate the entire train by a new method of multiple-unit control. Each of the cars carries a controller for operating its two motors, but when the motor cars are coupled together in a train, the controller of each car is operated by a compressed

ELECTRIC TRAIN OF THE FAYET-ST. GERVAIS-CHAMONIX LINE

VIADUCT OF SAINTE MARIE ON THE CHAMONIX LINE

air motor. All the air motors are connected through a piping which passes forward to the main pneumatic controller on the front car. By varying the air pressure, the motorman in the front car is able to change the position of the controllers on all the cars of the train.

Before the recent extension of the electric section, passengers were obliged to stop at Chamonix and to return thence over the same route. However, it was desired to continue the line through the valley at the base of the Mont Blanc range, and it was accordingly extended as far as Chatelard, on the Swiss frontier, which gave it a total length of 21.6 miles and enabled it to make connection at this point with the recently-built Swiss electric line. The route thus continues through a most picturesque mountain region, one which was scarcely visited before the opening of the new electrical railroad. The Fayet-Chamonix-Chatelard line is controlled by one of the leading French railroad companies, the Paris-Lyon-Mediterranean Company, to whose chief engineer, M. Poulet, we are indebted for the above data.

The new Swiss line, which connects with the Chamonix railroad at the frontier, is controlled by another company, and the method of operating this railroad differs considerably from the one employed in the former case. On the Chamonix line it was found that it could be operated throughout the whole course by simple adherence, by placing motors upon each of the cars, since the gradients of the road would permit of using this method. On the Swiss line, however, one stretch of the road lies on a heavy gradient, and here the rackrail system had to be introduced. The remainder of the road is operated by simple adherence, so that this line is an example of the few roads in Europe employing a combined rackrail and adherence system. The motor cars had to be designed with a view to this end, and

RACK RAILWAY TRAIN ON THE MONT BLANC RAILROAD ASCENDING TO THE MER DE GLACE

thus they offer some interesting new features. We had occasion recently to take a trip over the new line, and will mention some of the most striking innovations. As far as we know, no description of the road has been published outside of Switzerland, and we are indebted to M. Loew, the chief engineer of the company, for the data given below.

CHATEL-ST. DENIS STATION ON THE MONTREUX-BERNESE-OBERLAND RAILWAY

Starting from Martigny, a station on the Swiss Federal road in the Rhone Valley, the electric railroad proceeds through the rocky valley of the Arve, mounting a steep gradient in order to reach its terminus near Mont Blanc at Chatelard, where it connects with the French line. From Martigny to Vernayaz, the line follows the Rhone Valley at a nearly level grade for about three miles, but at the latter point it commences to climb the mountain side on the rack-rail section, which has a gradient of 20 per cent., and is about 1½ miles long. On this section are three tunnels, one of which is 440 feet long, and several bridges and viaducts. The rack-rail section ends at Salvan, and the remainder of the line for 7.2 miles runs by simple adhesion to the terminal at Chatelard. On the adhesion sections the maximum gradient reaches 7 per cent.

In order to operate the train on the adhesion and rack-rail sections, trains are composed of an electric locomotive of special design, and a number of cars which themselves are fitted to run as motor cars. These latter cars are also adapted to run singly upon the line, as will be seen in the illustration, as well as the electric locomotive which is shown attached to a train of motor cars. While the Chamonix line takes all its current from a third rail, the Martigny-Chatelard electric road uses an overhead trolley system upon the first adhesion section, and the live rail for the remainder. The line is operated upon 750-volt direct-current. The electric locomotive is equipped to drive the main wheels from the

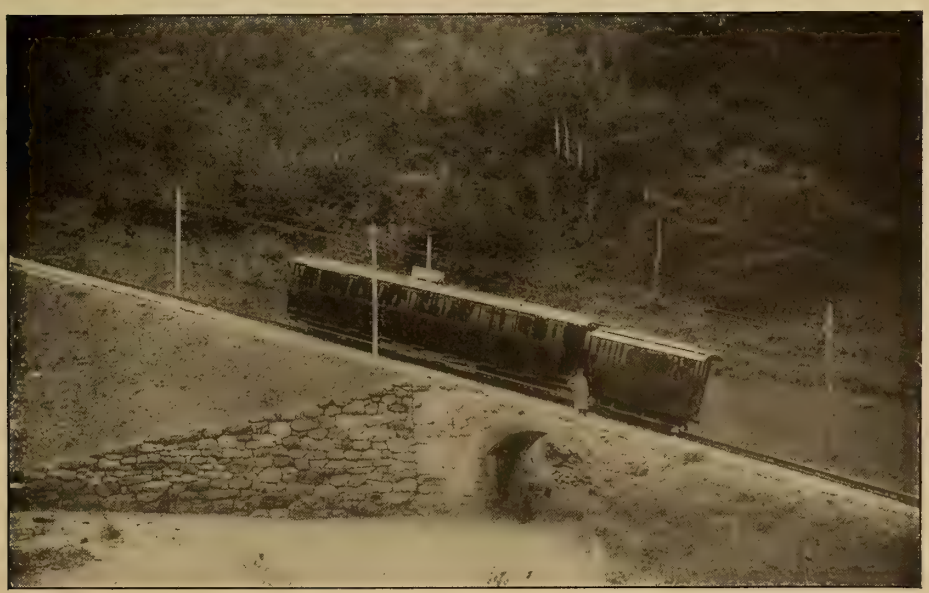
ELECTRIC CAR ON THE MONTREUX-BERNESE-OBERLAND LINE

electric motors, and on the other hand to operate the pinions for the rack rail. A type of motor car is constructed for the present line which has some interesting features. The chassis is mounted upon double bogies. Each of the latter is equipped with two motors, one of which drives the corresponding axle, being placed, contrary to the usual method, upon the outer side of the axle. One set of double-reduction gearing from the motors drives the main wheels, and a second and independent set is connected to the pinions. The motors are of the four-pole, ironclad type and develop 60 horse-power each, making 240 horse-power for the entire car. One noteworthy feature is the multiple-unit control, which is used to operate the controllers of each motor car from the locomotive when the latter carries a train of motor cars. On each car is mounted an electro-magnetic relay, which has a circular motion and thus rotates the controller of the car. On the locomotive there is a main controller which, when rotated, causes a corresponding rotation of the relays, so that the controllers of the cars accupy the same angular position as that given by the motorman.

A very successful application of the combined gasoline and electric system is made upon one of the most important light railroads of Hungary, namely the Arad-Csanad line, which comprises 225 miles of standard gauge road and 105 miles of narrow gauge, making 330 miles in all. These lines are situated southeast of Budapest and carry a heavy passenger traffic. Since commencing the use of gasoline trains, the railroad company has found them to be of such a great advantage for this class of traffic that, at present, they are operating the lines with them almost exclusively. Trains are made up from a locomotive, or rather motor car, and from one to five standard cars. At present there are

about forty locomotives in use, ranging from a heavy 80-horse-power type to the 30 and 20-horse-power locomotives. The petrol-electric group in the heavy locomotives consists of a Westinghouse, six-cylinder gasoline motor connected to a direct-current generator. Since the introduction of the present system, the traffic has increased very much, and the lines are better patronized by the public. This is seen from the fact that while other light railroads gave but 6 or 7 per cent. increase within recent years, the Arad-Csanad lines showed 25 per cent. increase for the same period.

One of the most recent mountain railway enterprises in the Mont Blanc region is the light steam-railway line which has been built near Chamonix. It is known as the Montenvers line, and is designed to take tourists up the steep mountain side, so as to enable them to reach the immense glacier known as the Mer de Glace, which is one of the most visited places of this region, lying amid lofty mountain peaks. Before the above-mentioned railroad was built, tourists had to make a difficult climb either on foot or on mule back over a steep and rocky mountain path, and the ascent and descent took the greater part of half a day. There was thus a great demand for a comfortable and rapid means of reaching this elevated point. By the new railroad, the Mer de Glace, or the station of Montenvers, which overlooks the great glacier, can be reached within fifty minutes after a comfortable trip, so that the view of the glacier can be enjoyed without fatigue. The new railroad starts from the electric railroad at the station of Chamonix, and climbs the mountain slope in a zigzag path, the difference of level being 3,161 feet for a distance of 3.2 miles of the railway, the maximum gradient being about 22 per cent. The track is laid with a 45-pound rail on a 1-metre gauge, with metallic ties. The rails are secured to the ties by hook bolts on the Rochet-Schneider system. Between the rails is laid the Strub rackrail, which is firmly attached to the ties. The rackrail has a head which resembles the usual rail head, so that



RACK RAILWAY TRAIN ON THE STANSTAD-ENGELBERG LINE

a grip brake can be used to clamp under the head and give a tight hold in order to prevent the locomotive from lifting off the track. Trains are in general made up of a light locomotive and two passenger cars. Five locomotives are in use at present, manufactured by the Winterthur Locomotive Works, weighing 18 tons empty and 24 tons when running in service. On the locomotive are two pinions which engage with the rackrail, while four different sets of brakes are provided. There are two band brakes upon drums, besides an air brake and an automatic, steam-operated brake of new design, which is put into action by a ball governor when the train runs above the proper speed. The Langen smoke-consuming apparatus, in which steam is delivered over the furnace grate in order to aid in the combustion, is used on the locomotives which are designed to give about 250 horse-power, and are placed in the rear of the train so as to push it up the incline. The cars have sixty places each, and are of the double-bogie type. The total weight of the loaded train is 45 tons. The Montenvers line started in operation during the last season, and it has already proved quite a success.

The Montreux Bernese Oberland electric line was designed in order to afford a connection from the shores of Lake of Geneva to the Oberland region, and it runs through a mountainous and picturesque country. Its starting point is at Montreux, which within recent years has become one of the best-known of the Swiss resorts in the region. As the gradients of the road are high, the maximum being 6.7 per cent., it was not considered advisable to use electric locomotives, as the weight of such would have to be very great in order to obtain an adhesion sufficient to take a heavy train. Besides, as the traffic is irregular and depends on the season and the weather, the heavy locomotives, in

CAR ON THE JUNGFRAU RAILWAY PASSING THE EIGER MOUNTAIN

many cases, would be required to take very light trains. Under these circumstances the use of motor cars and trailers was preferred. The present type of motor car weighs 30 tons when fully loaded for 52 places, and the cars are mounted on double bogie. Four ironclad motors, one for each of the axles, are employed, and the motors are designed to give about 70 horse-power each, having a gear reduction of 1 to 4.33.

use upon suburban sections of the steam railroads, in order to provide for the lighter traffic and thus replace the steam locomotive. At present we find the storage-battery cars in use upon no less than 740 miles of railroad in Germany, representing suburban lines, for the most parts radiating from the leading centres, such as Dantzig, Hanover, Cologne, Stettin, and so on. The Prussian railway administration is taking

ELECTRIC RAILROAD TRAIN ON THE JUNGFRAU

The overhead trolley system is used here, working at 700 volts, and employing the pantagraph trolley. The total length of the line from Montreux by way of Montbovon to the terminal at Zweisimmen is 37.2 miles. At this latter point connection is made with a steam railroad, which runs from Zweisimmen to the region of the lake of Thun, in the Bernese Oberland.

A storage-battery motor car is in use upon the Prussian State Railways, and it is of a somewhat novel type. It is designed principally for

measures to use the cars upon about 500 miles of railroad sections before 1910. At the time of this article being written, 57 cars are in use, the batteries being supplied by the Accumulatoren-Fabrik Company. A double car is used, consisting of two similar half-cars coupled at the middle and having a total length of 84.5 feet between buffers. Of the four axles, the two inner ones carry electric motors, each of these developing 80 horse-power. The storage battery consists of 168 cells in 12 wooden cases. Six of the cases,

holding 14 cells each, are placed in the compartments at each end of the car. The cells give a combined pressure of 310 volts for the motors. Such cars will travel for a 60-mile distance before recharging.

In Italy an electric railroad running through the valley of the Brembo has been in operation for some time past, and it is an example of the use of the Westinghouse single-phase system for electric locomotives. The electric outfit is built at the Havre works of this company. A 300-horse-power electric locomotive is used, containing four ironclad, four-pole motors of 75 horse-power each. Current is taken from an overhead trolley line, which is mounted on the catenary suspension system.

An extensive suburban system of lines branching out from Rome includes three sections running to the localities of Grotta Ferrata, Frascati and Rocca di Papa, covering a total length of 24.6 miles. There is used a double-decked motor car, equipped with Thomson-Houston apparatus, built at the Paris shops of that company. The cars have four motors of 60 horse-power each, and current is supplied from an overhead wire at 650 vaults.

We also illustrate the Stanstad-Engelberg mountain line in Switzerland. This starts from the shore of the lake of Lucerne and ascends to Engelberg, which is a well-known resort. The line uses a type of electric locomotive which is designed to work upon a rack-rail section. This section of the line is 0.9 mile long and has a 25 per cent. grade. Built somewhat like the locomotives of the Jungfrau electric road, the locomotives on this line have 13 tons weight and are equipped with two three-phase motors of 75 horse-power each.

ELECTRIC CAR OF THE MOUNTAIN RAILROAD ON THE VIRGL, NEAR BOZEN, TYROL

Current is taken from a 750-volt line by a pantagraph trolley.

The views given of the Jungfrau electric line will give an idea of its picturesque character. It is, in fact, one of the most remarkable of the Swiss lines. The rack-rail system is employed for this road, using a light locomotive of 150 horse-power, which is attached in the rear of the train and pushes the cars up the grade. An overhead trolley is employed, and the locomotive uses four separate trolleys of the ordinary kind. The station of Eiger is cut in the rock and lies at 10,450 feet altitude, and from this point there is a most remarkable view over the mountain peaks and glaciers.

Among the cable roads, which present some interesting features, we illustrate an incline recently constructed in Austria by the Berne Iron Works. It is known as the Virgl incline, and reaches an elevated point in the vicinity of Bozen. Another engraving shows a view of the Stanserhorn incline in Switzerland, which is built up a steep mountain slope, and it reaches the summit lying at an altitude of 6,270 feet. It is installed by the Industrie Electrique Company, of Geneva, who also constructed the rack railroad illustrated here. This line reaches the summit of Mont Salève, which affords a wide view over the city of Geneva and the Lake.

IRON AND STEEL PRODUCTION IN CANADA

By T. Good

ALTHOUGH the production of iron has been carried on in Canada for more than one hundred years the industry attained little importance until quite recently. The total output of pig-iron in the whole Dominion did not reach 60,000 tons in any year until 1895. Last year the output was only a trifle short of 700,000 tons. Steel and various steel products are also being manufactured in considerable and increasing quantities. The rail mill capacity alone is now equal to 400,000 tons annually. Fresh capital is flowing into the Canadian iron and steel industry pretty freely, productive capacity is being largely increased, many new developments are under way, and the trade is likely to take high rank in the near future.

It is not more than five or six years since the iron and steel-making resources of Canada were described as inferior by one of the greatest authorities, for the iron ore mines were at long distances from the coal fields and charcoal had generally to be used for smelting purposes. Despite liberal bounties on production and fair protection from outside competition, little real headway was made and practically no profits were realized. In fact, much money was lost in Canadian iron enterprises. One concern was carried on for twenty years without yielding a dividend. Lately, however, vast and rich deposits of iron ore have been found in fairly convenient localities, large coal areas have been discovered, and better transit arrangements are being made. There no longer seems any reason why Canada should not become one of the world's greatest iron producers. The foundations of the industry in huge and cheap supplies of raw material on the one hand, and in a rapidly growing home market on the other, are thoroughly sound.

It is now known positively that iron ores abound in practically every province of Canada. Only eight iron mines are in operation, and only one of these is producing as much as 100,000 tons of ore in a year, it is true; but active preparations are being made in the Eastern provinces for exploiting the recently proved deposits of ore on a large scale. At present the chief Canadian blast furnaces draw most of their ore from Belle Isle, in Conception Bay, near St. Johns, Newfoundland. Newfoundland is very rich in iron ores, and nearly 1,000,000 tons are raised annually, most of which is used in Canada. But enormous and rich reserves of hematite ore have been found in New Brunswick, within easy distance of large coal fields. Deposits of huge quantity and high quality have also been proved in Ontario, Quebec and Nova Scotia in the east, and in Vancouver and British Columbia in the west. Recent investigations conducted by the Department of Mines, coupled with private prospecting, inspire the hope that Canada is as rich in iron and steel-making materials as the United States.

In the west, in Vancouver and in British Columbia, there are vast reserves of fine coal. Near Edmonton, Alberta, rich coal areas have been proved which are regarded as extensions of the well-known Crows Nest Pass seams. A powerful syn-

dicate is being formed to get this coal, and a line of railway is to be constructed to open up the new field. In the extreme east, round about Cape Breton, there is an abundance of coal and a few prosperous collieries. In Toronto a company has just been organized, with a large capital, to operate three groups of coal mines in West Virginia and Ohio (U. S.) for the supply of the Canadian trade, via the Lakes.

Already iron ore from Newfoundland is landed at Sydney, within 10 miles of the Cape Breton coal mines, at a trifle less than 10*s*. a ton, and pig-iron is being produced at little more than 30*s*. a ton. The manager of one of the Canadian steel mills claims that he can now make rails at $6 a ton less than they can be produced in Pittsburg. It must be remembered, of course, that the Dominion Government pays liberal bounties to the producers of iron and steel from Canadian ore; also, that most of the steel makers have their coal free of the usual royalty, have their plants erected on free land, and are exempt from local taxation for a long term of years.

The largest of the Canadian iron and steel concerns is the Dominion Iron & Steel Company, of Sydney, Cape Breton, organized about eleven years ago by the directors of the Dominion Coal Company, a firm with collieries within a very few miles of the Sydney furnaces. As the Dominion Iron & Steel Company has an abundance of good coal in the immediate vicinity of its furnaces, has its own iron mines on Belle Isle, and its chief steel plant on Sydney harbour, it is well circumstanced naturally and geographically. The plant, apart from mines and cokeries, comprises four modern blast furnaces, ten open-hearth steel furnaces, two Bessemer converters and three rolling mills. The mills are capable of turning out 9,000 tons of rails and 7,000 tons of rods, bars, etc., in a month. The capital of this concern stands at £1,200,000. Additional capital is about to be raised and the works largely extended. The dividend paid last year was 5 per cent. The company earned nearly £250,000 in government bounties in the last financial year. It was this concern which recently sent a large consignment of steel rails into England, underselling the home makers. It is proving a keen competitor with British, German and American firms in several markets. It is reported that a syndicate, representing the controlling interests in this company and the Dominion Coal Company, is seeking to bring about an amalgamation, or at least a combination, of most of the leading coal, iron and steel concerns in Canada.

The second largest iron and steel concern in the Dominion is the Agloma Steel Company, a subsidiary of the Lake Superior Corporation, a powerful company recently formed to exploit Canada's iron-making resources. The Agloma plant is situated at Sault Sainte Marie, Ontario. This was the first plant in Canada to adopt Bessemer converters, about nine years ago. The plant comprises two blast furnaces, two converters, four open-hearth furnaces, seven cupolas and a rail mill. Two large new blast furnaces, another rail mill, a merchant mill and a set of coke ovens are now being constructed. In the last financial year the Agloma Company earned over £10,000 in bounties.

Third in importance, measured by output, is the Hamilton Iron & Steel Company. This firm is established at Hamilton Bay, on Lake Ontario. There are two blast furnaces, four open-hearth steel furnaces, billet and structural steel mills, hammer shops, axle and spike plants, etc. This company had more than £40,000 in bounties last year.

Next comes the Nova Scotia Steel & Coal Company. This firm, like the Dominion Company, has its chief plant near Sydney harbour, and owns both coal and iron mines. Be-

sides coking ovens, a smelter, four open-hearth furnaces and other plant at Sydney, this company has a rolling mill and a foundry at New Glasgow, another smelter at Ferrona, and plate, bar and structural mills at Trenton. This company was first established at Trenton in 1872. It earned about £37,000 in bounties in the last financial year.

Fifth in order of output is the Canada Iron Furnace Company, a subsidiary of the Canada Iron Corporation, Limited. The Furnace Company operates eight separate plants, seven in the Province of Quebec and one in Ontario. At Midland, Ontario, it has a blast furnace which supplies pig-iron for its iron and steel works at Three Rivers and elsewhere. The concern is somewhat handicapped by having to import its coke all the way from Connelsville, but is expecting to have nearer supplies shortly.

The Londonderry Iron & Mining Company, which comes sixth in order of output, merits special mention. This enterprise was founded in 1847, but for many years yielded no dividend. It was to keep this establishment on its feet that the first bounties on iron production were granted by the Dominion Government in 1884. Other enterprises, started in the fifties, sixties and seventies, mostly with United States capital, collapsed; but the Londonderry people struggled on, without a dividend for more than twenty years, until, in 1883, bankruptcy could no longer be avoided. The plant was in the hands of the receiver when, at the instance of Sir Charles Tupper, the first bounties were paid in 1884. The concern was rescued, and is now earning about £7,000 a year in bounties.

Besides these half-dozen notable companies there are in Canada the Lake Superior Iron & Steel Company; the Atikokan Iron Company, with a plant at Port Arthur; the Deseronto Iron & Steel Company, Ontario; the Ontario Iron & Steel Company, a new concern, with furnaces and a foundry at Welland, using natural gas and oil as fuel; the Drummonds, of Montreal, who have four pipe foundries; the Montreal Rolling Mills Company; the Electric Reduction Company, of Buckingham, Quebec, who make ferro-chrome, ferro-silicon, etc.; Electro Metals, Limited, of Welland, Ontario, who are manufacturing steel by the new electro process; there is John McDougall & Co. of Montreal, a subsidiary of the Canada Iron Corporation; and a large agricultural implement works at Toronto, as well as boiler, bridge, engine and electrical works. There is also a shipyard of some importance at Collingwood, where a vessel 365 feet long has just been launched, and where preparations are being made for building much larger vessels. And there is some well-founded talk of establishing a modern shipbuilding industry on the Atlantic shore.

That there is ample room for a big and progressive steel industry in Canada, now that an abundance of raw material is known to exist, is fully demonstrated by the fact that the Dominion imported over a million tons of iron and steel last year, despite the record home production. There is a rapidly increasing population; extensive railroad construction is on hand and projected; steel is entering largely into house building; wooden bridges are being replaced by steel; the demand for agricultural implements is expanding very largely; and, finally, the Dominion is setting its heart upon a great mercantile marine—and even a navy.

In view of the recent importation into England of Canadian steel rails and the discussion it has provoked, we may venture to a brief account of the bounty system which, it is contended, is really responsible for this competition from a new quarter. For more than twenty-five years, as is well known, the Dominion Government has been not merely gen-

erous, but lavish, in its favours to the iron and steel producer. Besides the direct bounties, the smelters have often had free land for their works, their coal royalty free, and have been local tax-free for thirty years in some cases. But the current idea that these Canadian steel rails have been dumped into this country as a direct result of the bounty system is scarcely fair to the Dominion statesmen. When the last Bounty act was carried, between three and four years ago, the stipulation was made that bounties were to be granted only in respect of iron and steel consumed in Canada—not on materials or articles for export.

In none of the Bounty acts carried between 1883 and 1903 was any distinction drawn between goods produced for home consumption and those made for export. As a matter of fact, the export trade was of little account. Only occasional cargoes of pig-iron were sent to the Clyde until quite recently. But when the last Bounty bill was being drafted there was a prospect that Canadian steel makers would soon be in a position to indulge in an export trade. Besides that, it was announced that the United States Steel Corporation had acquired nearly 1,000 acres of land at Sandwich, Ontario, intending to erect a plant there and manufacture for export under the Canadian bounty law. The Dominion statesmen were at once alive to the possibilities of the situation. They decided to adopt safeguards. In introducing the last Bounty bill the Finance Minister, Mr. Fielding, said: "We propose that these bounties shall not apply to iron and steel that is exported. There are rumours that the great Steel Trust of the United States may come to Canada to do business. If it comes in the ordinary way, well and good; but if it comes here to make iron and steel for export, it may add largely to our burden. We think it is well to have it understood that we are giving these bounties for the encouragement of iron and steel production for consumption in Canada, and if any concerns undertake to export iron and steel goods they shall not be entitled to the bounties on them." But for that stipulation it is highly probable that the Steel Trust would have proceeded at once to erect a plant in Canada, and would, by this time, have been exporting bounty-fed steel.

The present Bounty act, which came into force in 1907, provided—

"That it is expedient to * * * authorize * * * the following bounties on the undermentioned articles manufactured in Canada for consumption therein, viz.:

"(a) In respect of pig-iron manufactured from Canadian ore, or the proportion from Canadian ore, produced during the calendar years 1907, $2.10 per ton; 1908, $2.10 per ton; 1909, $1.70 per ton; 1910, $0.90 per ton.

"(b) In respect of pig-iron manufactured from foreign ore * * * 1907, $1.10 per ton; 1908, $1.10 per ton; 1909, $0.70 per ton; 1910, $0.40 per ton.

"(c) On puddled iron bars * * * 1907, $1.65 per ton; 1908, $1.65 per ton; 1909, $1.05 per ton; 1910, $0.60 per ton.

"(d) In respect of * * * wire rods not over 3/8 inch in diameter, manufactured in Canada, from ingredients of which not less than 50 per cent. of the weight thereof consisted of pig-iron made in Canada, when sold * * * for use * * * in Canada, on such rods made after December 31, 1906, $6 a ton.

"(e) In respect of steel ingots * * * 1907, $1.65 per ton; 1908, $1.65 per ton; 1909, $1.05 per ton; 1910, $0.60 per ton."

It may be mentioned that Newfoundland ore is classed as "foreign."

While the bill was in the drafting stage a company was preparing to establish a plant at Welland for the purpose of smelting iron and making steel by electricity, and a special

clause was added authorizing an additional bounty on iron and steel made by that process up to the end of 1912. The total amount paid in iron and steel bounties under this act last year was $1,864,000, and in 1908, $2,302,000.

It is now reported on high authority that the iron and steel bounties which expire this year will not be renewed, because the Canadian iron and steel industry can now stand on its own feet. In the words of the *Times* correspondent, "it is finally and definitely announced that the bounties * * * will not be renewed." But those interested in the withdrawal of the Canadian iron and steel bounties and the issues involved therein would do well not to be too confident. The leading iron and steel producers in the Dominion are going to make a strong appeal for renewal. And they will be able to make out a very good case. The government, it must be noted, always lends an attentive ear to the manufacturers, especially the iron and steel makers. This has been aptly described as the government's "petted industry." It is not very long since the Finance Minister declared that the Treasury had not lost a single dollar by granting bounties upon iron and steel, for these bounties had been instrumental in building up new industries and cities which had contributed quite as much to the revenue as they had drawn out. That statement passed absolutely unchallenged. In these circumstances we should not be surprised in the least to see the bounty system continued. But, bounties or no bounties, the Canadian steel trade is destined to rise to a high status.

THE PROTECTION OF EMPLOYEES IN COTTON MILLS

By H. M. Crawford

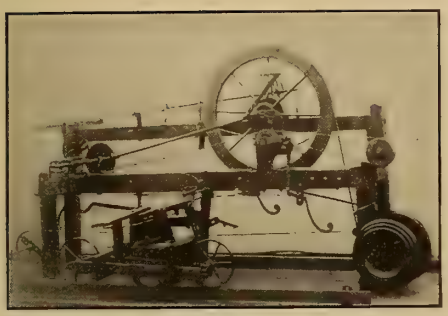


FIG. 1.—SAMUEL CROMPTON'S ORIGINAL MULE

"ACCIDENTS will happen." This is a trite saying sometimes made as if accidents were unavoidable adjuncts of our industrial system. To some extent this doubtless is true, but it is also certain that a larger percentage than is generally imagined may be reduced from the casualty roll.

Cotton-spinning mills in England, France, Belgium, Germany and the United States have, for a century at least, been prolific sources of accidents arising directly from the machinery in use, as distinct from other causes. It was this prevalence of injury among cotton-mill workers on the Continent that called into being the Society for the Prevention of Accidents in Factories in Alsace twenty years ago, and excellent work has been carried on by this society and its ramifications among the cotton mills of Alsace, Lorraine and Rhenish Prussia. It must, in fact, be credited to that disinterested body of mechanicians that they were the main pioneers of efficient safety devices for cotton machinery. During the last decade we in England have adopted several of these appliances, improved on others, and from the inspiration given by those early efforts our engineers and machinists have invented many more which do good service every working day in the mill. The United States are now actively falling into line, and insurance companies are giving serious attention to the proper safeguarding of machinery in mills under their supervision.

The machine of greatest import in a cotton-spinning mill (Fig. 2) is the self-acting mule. This, without doubt, is the most complex piece of mechanism in the whole factory, has received greatest attention from inventors and machinists generally, and performs work on which the strength and dignity of a mill depends.

When Samuel Crompton launched his invention on the factory world little could he imagine that after the lapse of a century we should retain the main principles of his machine intact, and he could never have regarded his innocent carriage and headstock (Fig. 1) as becoming the chief source of the accidents that come to a cotton mill.

Yet the mule has for long, unfortunately, borne this unwelcome characteristic. In 1900 some 1,500 cotton-spinning mills were in operation in Great Britain with 50 million spindles, consuming 3 million bales of cotton; and the number of accidents from self-acting mules alone totaled over 800, or an equivalent of the casualties due to *all* other classes of machinery used in cotton spinning. Then efforts began for the express purpose of reducing this number considerably by the provision of safety devices on certain dangerous parts of

FIG. 2.—NEW AND OLD TYPES OF COTTON-SPINNING MILLS
(The large mill is the Majestic Spinning Mill at Oldham.)

FIG. 3.—LITTLE PIECER CLEANING

the mule. Up to this time no fencing whatever was applied to faller hammers, carriage wheels, middle scrolls on back shafts and rim pulleys on headstocks. "Impracticable and unnecessary" were terms applied to this generous scheme of fencing, but patience and inventiveness prevailed. Guards were devised which, if properly fixed and carefully used, could not do otherwise than diminish the risks then run by operative spinners and piecers. The machine makers at once rose to the occasion and produced guards for their own mules which would in no way hinder the mechanical operations nor reduce the output of yarn.

A cotton mule contains some 1,200 spindles, a pair of machines being tended by an operative spinner and his two assistants—a big piecer, generally over the age of 16, and a little piecer under that age. These operatives work in light clothing

(Fig. 3), such as shirt and trousers, often enough in shirt only, with no covering to the head, neck or feet. Statistics collected during several years proved that the majority of accidents arose from the following parts of mules: headstocks, tightening pulleys on headstock square, quadrant pinions, back-shaft scrolls, drawbands and their pulleys, faller hammers and carriage wheels. Efficient guarding was, therefore, aimed at these items. Special regulations have also been provided for all cotton-spinning mills in the United Kingdom making it compulsory for the following parts to be securely fenced:

(a) Back-shaft scrolls, carrier pulleys and drawband pulleys.

(b) Front and back carriage wheels.

(c) Faller stops.

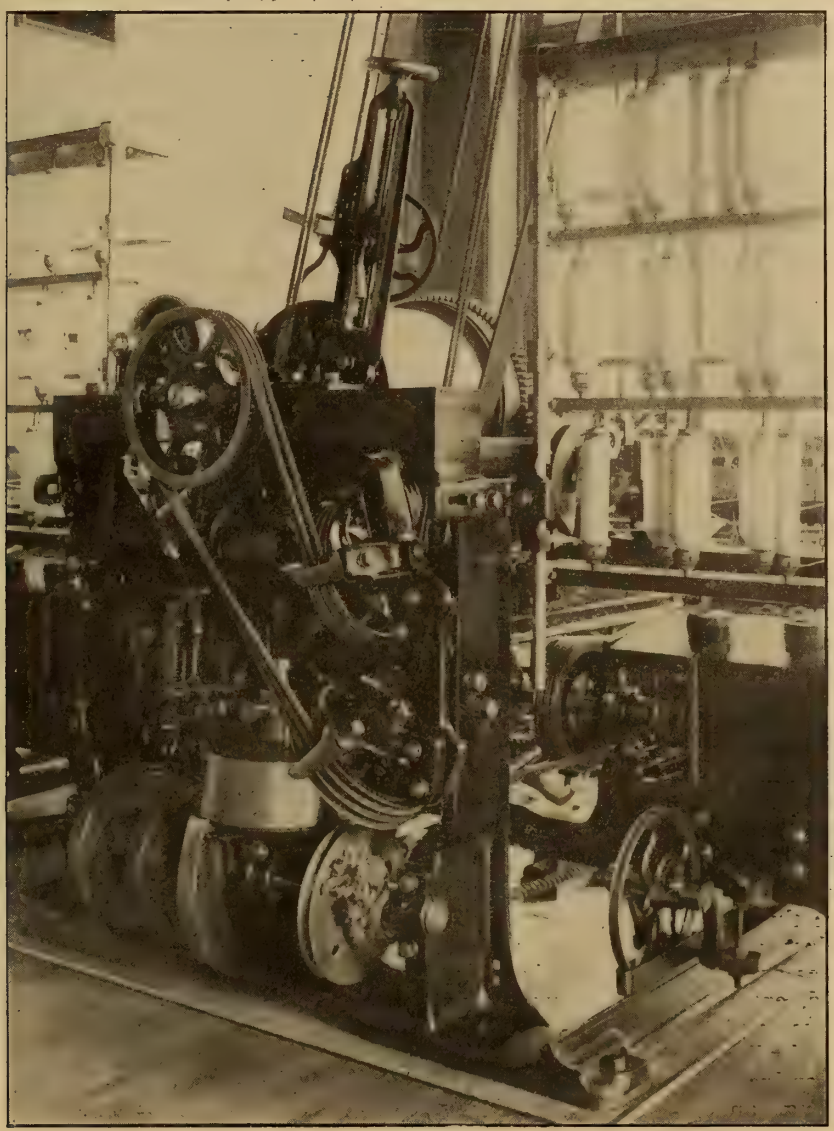


FIG. 4.—HEADSTOCK OF MULE

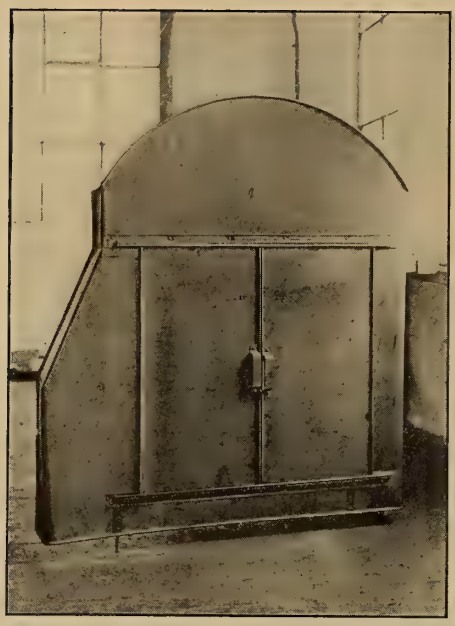


FIG. 5.—GUARD FOR BACK OF HEADSTOCK, WITH SLIDING DOORS

(d) Quadrant pinions.

(e) Back of headstocks, including rim pulleys and taking-in scrolls.

(f) Rim-band tightening pulleys other than plate wheels, connected with a self-acting mule erected after January 1, 1906.

The headstock (Fig. 4) is the "mainspring" of the mule, from which all its evolutions are directed. At the back are dangerous pulleys and wheel-trains where piecers and spinners must pass many times in a day when changing bobbins in the creels. The main rim pulley and rim carrier pulleys make 750 to 800 revolutions per minute, and if any hand-brush or cleaning cloth comes into collision with these parts physical damage is almost certain. Boy piecers have thus been flung to the floor or against adjacent parts of the machine; arms and legs have been fractured, entailing heavy insurance premiums and compensation amounts out of all proportion to the cost of preventive guards. For 18 to 25 shillings an efficient guard (Fig. 5) can now be supplied to the back of a mule headstock, covering all rim pulleys, bevel and spur wheels and the taking-in scrolls near the floor. Besides, the parts of the headstock required to be oiled periodically are made continually accessible by the inclusion of folding doors in the guard itself. The guard is so affixed to the headstock frame (Fig. 6) by means of latches that it can be moved bodily away in case repairs are required. No headstock guard is complete or efficient which does not adequately cover the scrolls near the floor.

At the front of the headstock—that is, in the "jenny-gate," where spinners and piecers spend the greater portion of their working hours, are the quadrant arm and its pinion (Fig. 7) on the right-hand side and the tightening pulley (Fig. 8) on the left. Both these parts have been prolific in serious accidents. The quadrant of a mule is reversible, like the movement of a carriage; its

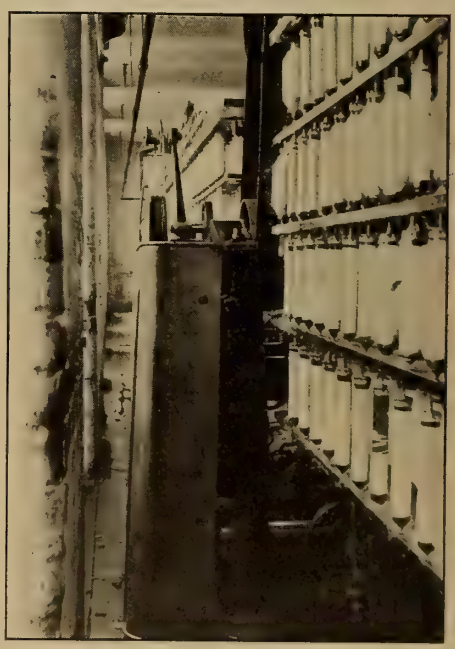


FIG. 6.—GUARD AFFIXED TO BACK OF HEADSTOCK FRAME

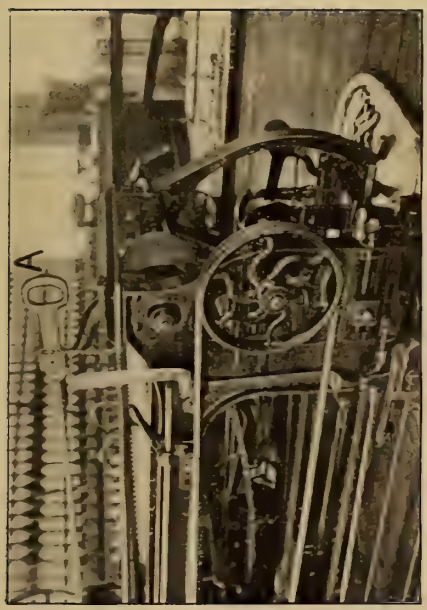


FIG. 7.—QUADRANT ARM AND SPURHAMMER

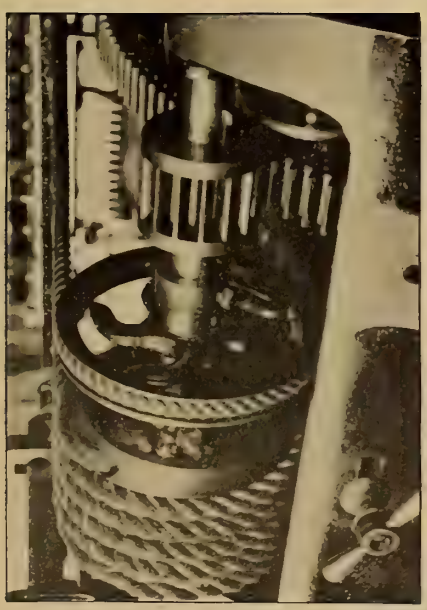


FIG. 9.—QUADRANT GUARD A (FIXED TO FRAME), AND GUARD B LEVERED ON IT

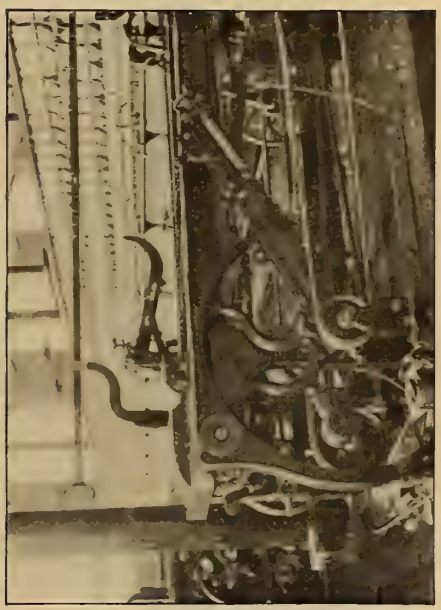


FIG. 8.—TIGHTENING PULLEY ON FRONT OF HEADSTOCK; ALSO STARTING ROD A WITH CHAIN AND PLUG

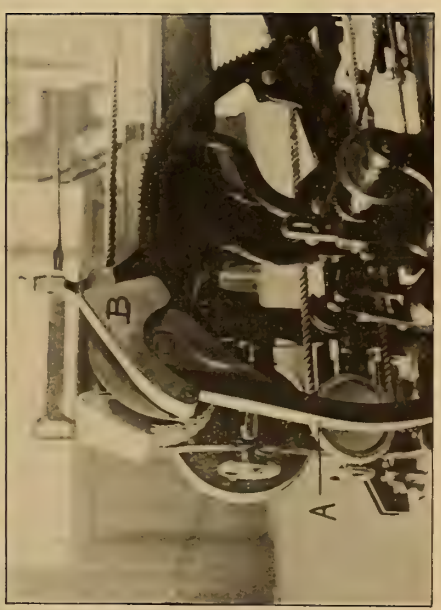


FIG. 10.—QUADRANT ARM OUTSIDE PLANE OF QUADRANT

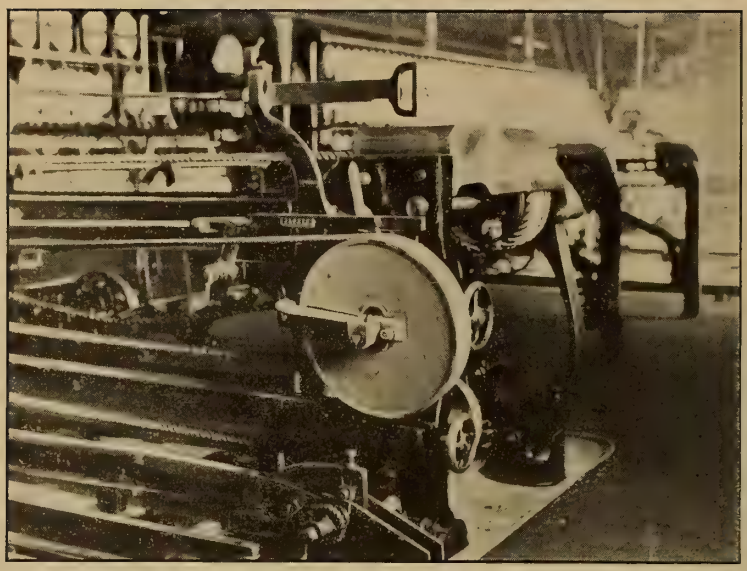


FIG. 11.—PLATE GUARD OVER RIM BAND TIGHTENING PULLEY

pinion, therefore, bites above or below, according to the falling or rising of the quadrant. When the quadrant is rising, the intake of the pinion is fairly protected by a trunk in which the quadrant runs; but when the quadrant falls its arm approaches so near to the pinion that fencing on this side has, up to recent times, been omitted. Now, however, various devices are in use which cover as far as possible the space—1, 2 or 3 inches—hitherto unprotected.

The quadrant and pinion may work inside the headstock frame and be provided with a high hood, precluding all risk of accident. Or the quadrant and pinion may be outside

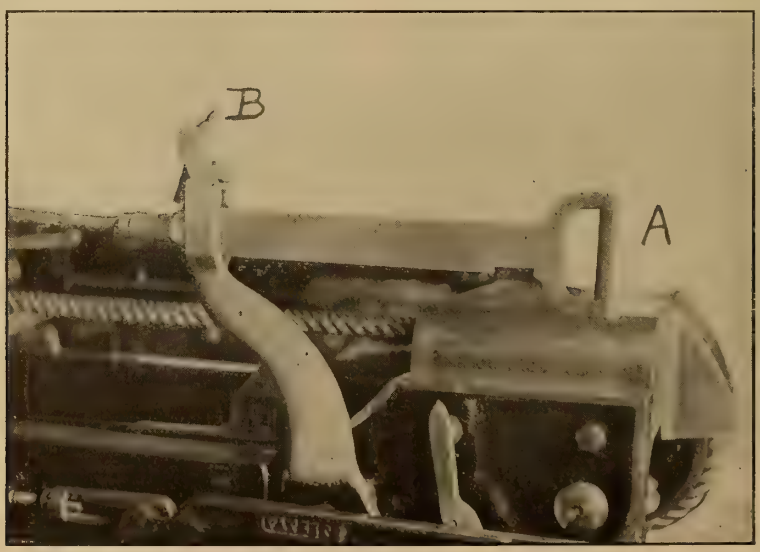


FIG. 12.—STARTING ROD A WITH DROP-LATCH B

the headstock frame, in which case the quadrant guard is fixed (Fig. 9), and to it is attached a pinion guard operated by the quadrant as it advances or recedes. When the arm advances the guard is raised on its fulcrum, and falls by its own weight when the arm recedes. The guard thus covers at all times the open space above referred to.

In both these types of mule the arm and quadrant teeth are in the same vertical plane. In some mules the arm is in a plane external and parallel to that of the quadrant (Fig. 10). In this type a guard is attached to the headstock frame, which covers the quadrant teeth entirely and allows the arm to travel by the side of the guard without impinging it in any way. Where, in the case of old machinery, the quadrant arm in its advance comes close to the pinion, a lateral plate-guard may be affixed, allowing the arm to pass inside.

Rim-band tightening pulleys, other than plate wheels, which have been erected since 1905 should be efficiently fenced. Several machinists now make these wheels without spokes, and of a smaller diameter than formerly. Where armed-pulleys are used a simple form of plate-guard (Fig. 11) is devised, which effectively covers the dangerous spokes and allows the spinner to tighten his bands. The difficulties which have arisen with tightening pulleys have been two-fold. Workmen's arms have been broken by the spokes owing to accidental starting of the wheel, or limbs have been severely abraded and burnt by friction against the revolving periphery. Both these exigencies are provided for by the plate-guard, which covers the whole area in which the pulley is required to move in the process of tightening the band.

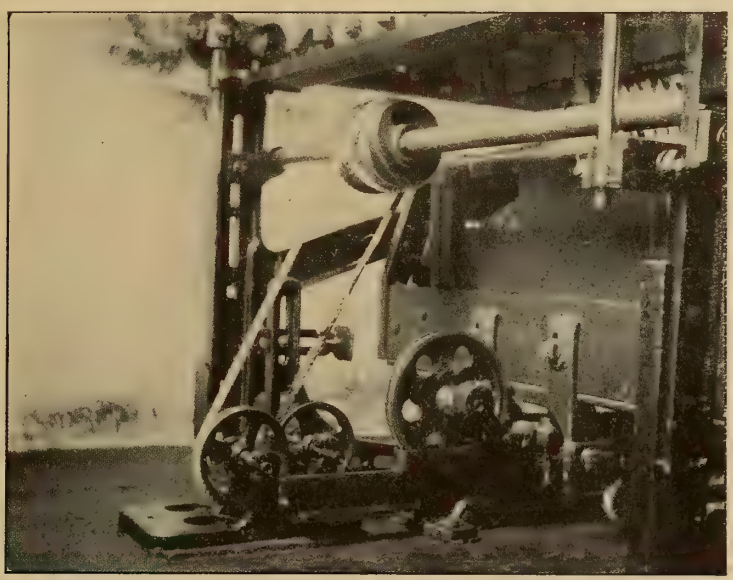


FIG. 13.—SCROLL-WHEEL AND ROPES UNPROTECTED

While noting parts in the square of the headstock, we should remember the importance of securing the safe working of the starting rod (Fig. 8). Serious and fatal injuries have frequently been caused by this rod escaping from its stopping point and thereby restarting the mule. The rod is, in all modern mules, provided with a notch about half an inch deep, which, on the cessation of the machine, falls on the lower side of a

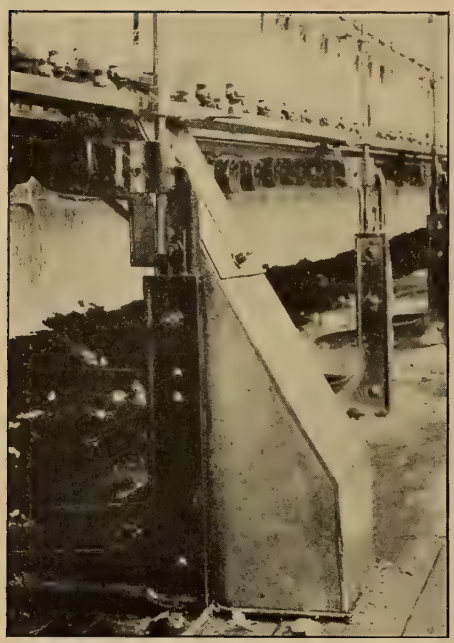


FIG. 14.—GUARDS COVERING SCROLL AND DRAWBANDS

slot in the rod guide. So long as this notch remains in the slot the machine is stationary. If by any means the notch is lifted from the slot the machine may start at any moment and do irreparable damage. Rods may be made quite safe by very simple means. It is customary for a wooden wedge to be inserted in the unoccupied portion of the slot when the notch is in place. In this way the rod cannot be lifted until the wedge has been removed. Another common practice is to place the notch in the slot, drill a hole through the rod and slot, and in this aperture fit a plug (Fig. 8) held by a chain to the machine frame. Similarly, by this plan the rod cannot be lifted from its safe-keeping until the chained plug is withdrawn. Another method is by means of a drop-latch (Fig. 12) which is so balanced that when it falls on the stopped rod this cannot be lifted from the slot until the latch is moved.

There are still in use in cotton factories mules of fifty years ago with round starting rods in place of the more modern ones, which have an oblong section. These round rods have no notch at all, and are liable to cause serious casualties. They can be safely secured by drilling a concentric aperture through the rod and rod guide and treating to a plug and chain. There need then be no fear of a mule re-starting "from an unknown cause."

The back shaft of a mule claims careful and detailed attention in all cotton-spinning mills. The toll of fractured arms and hands, and of limbs torn from their sockets by this shaft and its scroll-wheels, is indeed serious. It is common knowledge that the roller weights lying within the line of the back shaft and parts adjacent are cleaned while the mule is in motion. And with the back-shaft scrolls (Fig. 13) uncovered, the risks are so obvious and unwarrantable that guards are now required in all British factories.

Every mule is divided by the headstock into two unequal parts known as "halves," and a "half" generally contains in its back shaft three scroll

FIG. 15.—GUARD FOR CARRIER PULLEYS AND LOWER DRAWBAND PULLEYS

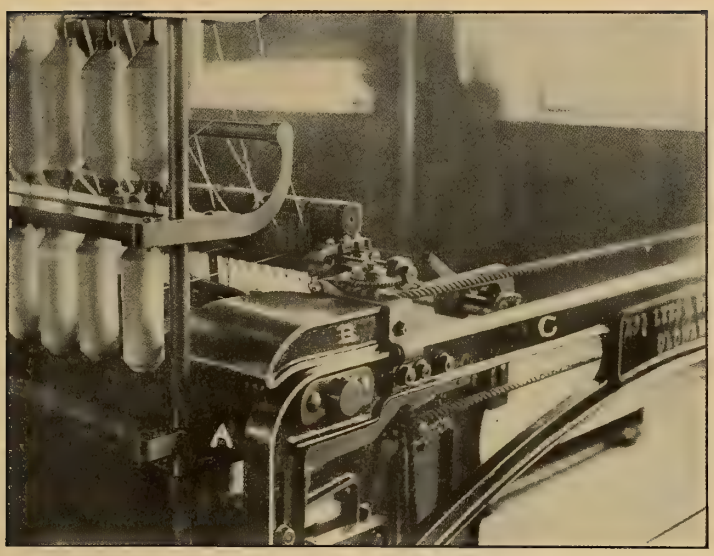


FIG. 16.—GUARD B OVER END SCROLL A

wheels, one close to the headstock, one at the end of the machine and a third about midway between the two just mentioned. The most serious accidents have come from the intermediate or "middle" scrolls and the bands or ropes running on them.

These scrolls are concerned in the traversing movement of the mule carriage. They are, therefore, reversible. Besides, they revolve at different rates, according to the directions in which the carriage is moving. If the carriage is moving outward—that is, towards the front of the mule—the revolution of the scroll is slow, about 8 inches per second. But when the carriage runs inward—that is, towards the creel of bobbins—the scroll attains a peripheral speed of 20 inches per second. If, therefore, a shirt-sleeve and then an arm get between the fast-moving scroll and its band, the limb is so fearfully twisted that amputation becomes necessary. To eliminate this grave risk guards are provided which encase the scroll on all sides. Fig. 14) except the inner and under sides; and in connection with it is another guard which encloses the carrier pulleys (Fig. 15) near the creel board and the drawband pulleys near the floor. We have thus a complete set of guards for the middle scroll and its bands. The end scroll is close to the terminal frame of the mule, and is covered with a guard (Fig. 16) the full breadth of the scroll. In former mules this

FIG. 17.—END DRAWBAND PULLEY WITH GUARD

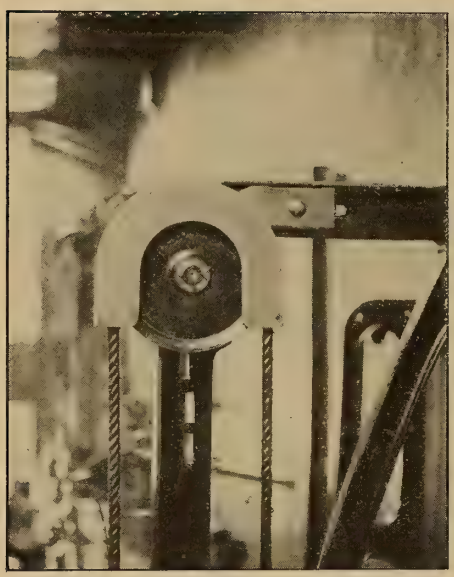


FIG. 18.—GUARD ON DRAWBAND PULLEY AT FRAME END

guard is too narrow and insecure; an additional plate is, therefore, riveted to this guard so as to bring it up to present-day standard. It has been urged in influential quarters that the under side of end scrolls should also be guarded, as a short band is connected to this scroll which draws inward when the carriage is at its greatest speed. If a boy piecer be picking "fly" from this short band when the carriage is on its inward run, he is in imminent danger of having his thumb or finger caught by the intake of the scroll and band.

It is seldom that accidents occur from the scrolls close to the headstocks. Covers are, however, made for these so as to minimize risk.

The terminal scrolls on the back shaft are connected by drawbands to grooved pulleys (Fig. 17) on the frame end of the mule. These pulleys are veritable traps if unfenced. Guards are provided which cover the intake (Fig. 18) of the bands so that casualties are obviated, except an occasional friction burn from handling the band itself. There are certain band pulleys in the centre of the jenny gate used for the purpose of steadying the motion of the mule carriage. These pulleys on earlier mules revolve vertically, and, being reversible, often cause severe accidents to piecers when not properly fenced. A complete cover (Fig. 19) is devised for their safety. In recent mules the pulleys revolve horizontally near to the floor, and are enclosed in an iron casing (Fig. 20) hinged for inspection purposes.

The mule carriage wheels (Fig. 21) in an ordinary spinning mill of, say, 80,000 spindles, run into thousands. Every carriage contains from twenty-four to thirty-two wheels divided equally at the back and front. Each pair, fastened on one bearing under the woodwork of the carriage, runs on a raised iron rod or "slip" which lies in the jenny gate, attached to the floor, at right angles to the carriage front. In each jenny gate there are thus twelve to sixteen slips for each mule. The slips are oblong in section, being set up on the narrow edge, and stand about 1½ to 2 inches above the floor. Each carriage wheel is grooved, having side flanges,

FIG. 19.—GUARDS OVER VERTICAL DRAWBAND PULLEYS IN JENNY GATE

FIG. 20.—GUARD B FOR HORIZONTAL DRAWBAND PULLEY A, IN JENNY GATE

FIG. 22.—CARRIAGE WHEEL GUARD FIXED TO THE WHEEL BRACKET

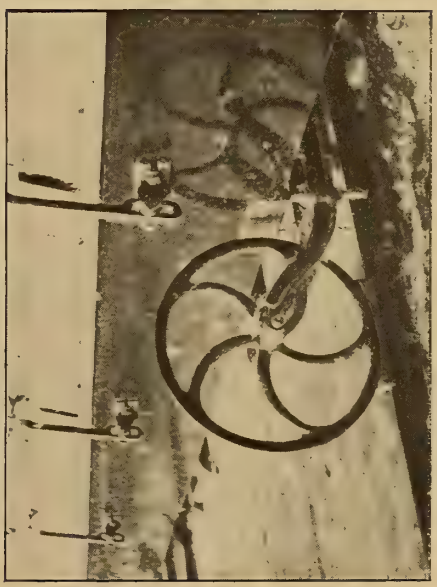


FIG. 21.—CARRIAGE WHEEL UNPROTECTED CARRIAGE RUNS TO AND FRO ON RAILS (SLIPS) INDICATED BY BOY'S FINGERS

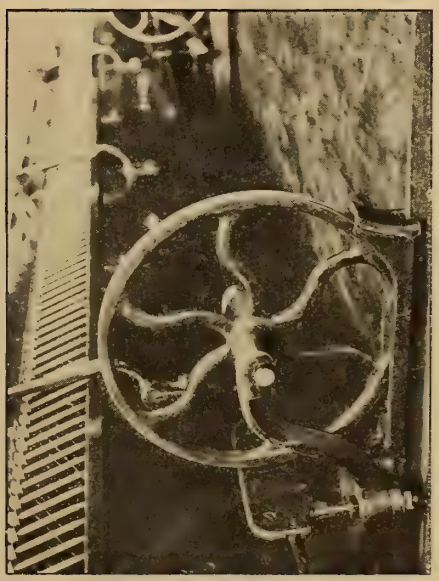


FIG. 23.—WHEEL GUARD RESTING ON SLIP.

FIG. 24.—GUARD WITH LIGNUM PLUGS AND SIDE PLATES, RESTING ON SLIP

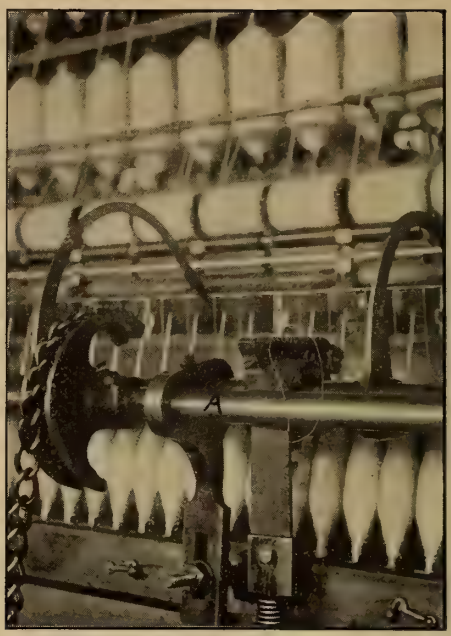


FIG. 27.—FALLER HAMMER ("MOUSE TRAP") READY TO FALL ON SHAFT A

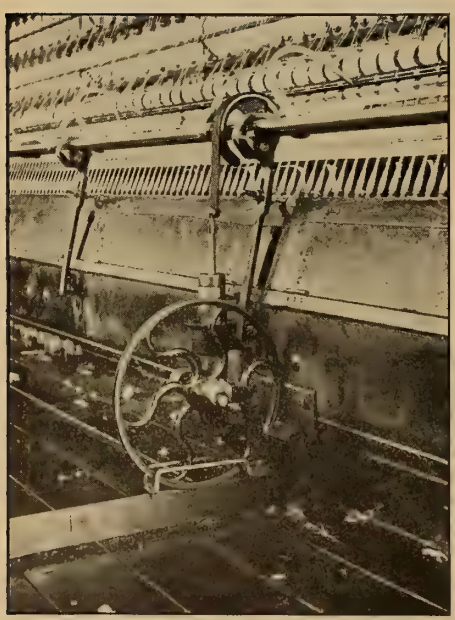


FIG. 25.—WIRE WHEEL GUARD FIXED TO WHEEL BRACKET

FIG. 28.—A GIRL AT THE COTTON MULE, PIECING THREADS

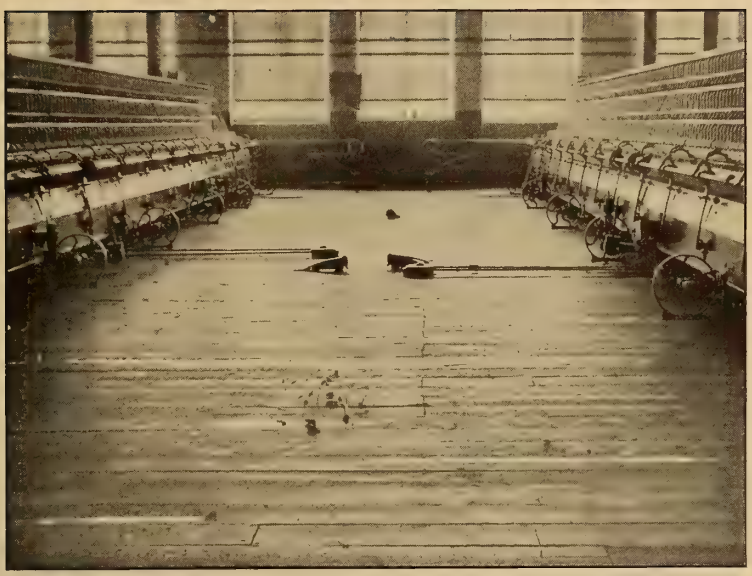


FIG. 26.—JENNY GATE WITH WHEEL PLATES (INSTEAD OF SLIPS), LEVEL WITH THE FLOOR

so as to run on the upper edge of the slip to and fro, as required. When yarn is being *twisted* the carriage runs outward; and when the yarn is to be *wound on* the spindle to form a cop the carriage runs rapidly towards the creel. These carriage wheels have been frequent causes of accidents in cotton mills. It is not uncommon for even practiced spinners and piecers to slide on the greasy floor and fall across the wheel slips. If the carriage is then advancing, severe injury may follow. The bulk of carriage-

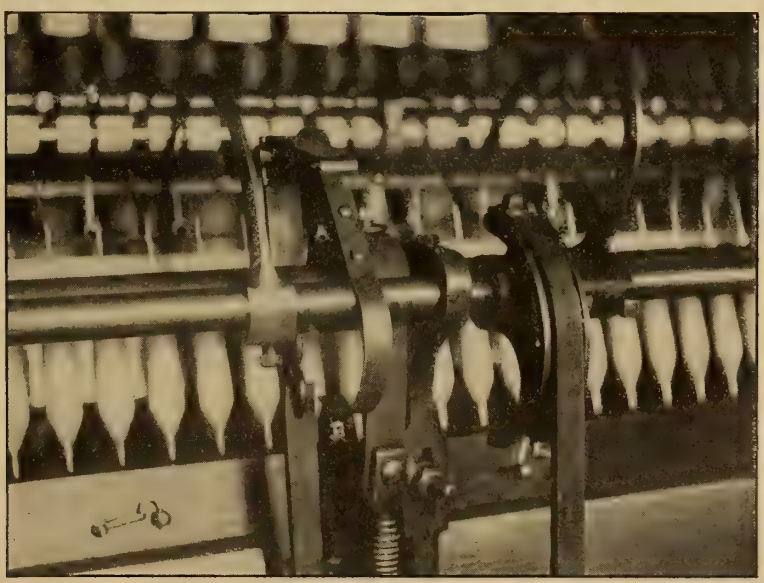


FIG. 29.—GUARD B FIXED TO FALLER HAMMER A

wheel accidents have come to piecers' fingers when picking loose "fly" from the rod itself or from the lowest part of the wheel. Preventive measures are varied in character. Some master spinners prefer a guard which is fixed to the wheel bracket (Fig. 22), and is thus held between the intake of the wheel and the iron slip on which it travels. In this case it does not touch the slip, being separated from it about ⅛ of an inch. This

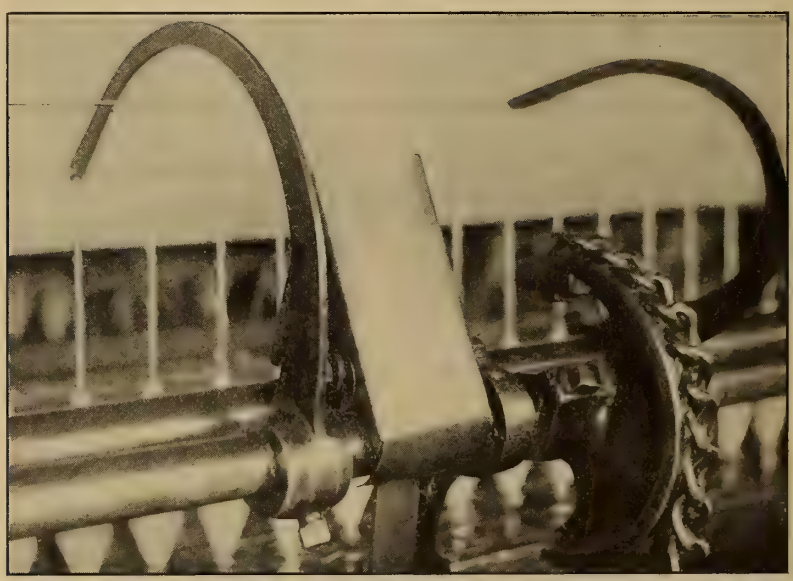


FIG. 30.—FALLER HAMMER GUARD FIXED TO THE SHAFTS. THE HAMMER IS FREE TO MOVE INSIDE

prevents any fingers reaching the intake of the wheel during its traverse. Other guards are devised to rest on the slip and be urged to and fro by the moving wheel. These are used in the form of one solid casting (Fig. 23); also, as a combination of side plates and end plates of *lignum vitæ* (Fig. 24). The end plates are bolted to the side plates and may be renewed after wearing. It is significant, however, that in six months' work these wooden plugs have abraded not more than 1-16 of an inch.

There is, in some mills, a marked preference for strong wire guards for carriage wheels. These guards are either suspended in two halves from the wheel axle, or they are attached to the wheel bracket (Fig. 25). If hung on the axle, they are coiled several times in front of the wheel so as to sweep away any feet or fingers that may be on the slip. This form of guard is particularly favoured when the slip is so short that the carriage wheel travels to its extreme limit. The guard can never fall over the end of the slip, as is sometimes the case with the iron-plate guards.

There can be no doubt whatever as to the immense boon arising from these wheel guards. Accidents from carriage wheels have been reduced to the extent of more than 50 per cent. by their adoption. In the matter of wheel slips a notable innovation has been made in some English spinning mills where iron plates (Fig. 26) have been laid level with the floor and upright slips avoided altogether. The wheels running on these plates have plain-edged peripheries.

Faller hammers are familiarly known in Cotton Land as "mouse-traps," from an awkward knack they have of trapping unwary fingers.

Each mule carriage has two shafts, one behind the other immediately over the spindles; on the back shaft the faller hammers are levered and their noses made to fall smartly on the front shaft (Fig. 27) as the carriage moves to and fro on its traverse. If now a boy's fingers be resting innocently on the front shaft just under the lifted nose of the hammer he will be severely crushed when the carriage reverses and the hammer suddenly falls. Quite a large number of juvenile piecers, boys and girls (Fig. 28) have lost terminal phalanges of fingers from this cause. The guards provided eliminate the danger. Where guards are fixed (Fig. 29) to the hammer itself they curl under the front shaft and cover the dangerous space immediately under the hammer. If not fixed to the hammer (Fig. 30) they are attached between the two shafts forming a hood within which the faller hammer moves independently. No fingers can then approach the hammers.

Every working day these simple devices prove their value. Faller hammer accidents have been entirely eliminated from many spinning mills, and where they do occur they are generally due to want of care or a faulty attachment of the guard.

By the aid of the fencing appliances the dangers of self-acting mules have been reduced to a minimum, and the working conditions of the operatives have attained to a degree of confidence and safety not known in the cotton industry before.

THE LIGHT RAILWAYS OF BELGIUM

By Lionel Wiener

MOST countries have found it needful of late years to complete their railway system by another, intermediate between railways and tramways. Such are the "Chemins de fer secondaires," in France, "Economiques" in Italy, and "Vicinaux" in Belgium. These latter are particularly interesting as being the outcome of a system of railways extending over the whole country, with the help of the government; their speedy growth and sound financial organization are equally remarkable.

Originally worked entirely by steam locomotives, the company has begun electrifying its system, and is about to electrify all the lines where there is sufficient traffic to pay off the working expenses. It is, therefore, interesting to examine its present situation and to see how this new phase will affect the general system.

Parliamentary bills have not only facilitated but often encouraged light railways development, and there is no doubt that the first of the two Austrian bills (May 23, 1883, and February 24, 1888) granting light railways a number of privileges drew the attention of Belgian legislators to the advisability of following on the same lines.

Austrian light railways are exonerated from duties of every kind, such as the obligation of providing post offices as the railways must, telegraph lines, etc. When there is a junction station between a light and a normal railway, the latter is obliged to work the joint station at its own cost, charging the light railway for its share of working expenses only; if needful, the main railway company may even have to work the whole of the light railway line, upon the same terms, and without profit. It must also carry all the light railway's building materials at cost price.

Now in Belgium railways belong to the State. It was, therefore, a foregone conclusion that the State should wish to own the Light Railway system as well. As a matter of fact, this is only partly the case, as the State and corporations have a share in the light railways, but they have not exclusive control of them. The "Société Nationale des Chemins de fer Vicinaux" was promoted in 1885, with the object of building a complete light railways system in Belgium. These lines were intended to be feeders to the railways, and mostly ran from an important town or village that had been neglected by the trunk lines to some neighbouring station. The system has expanded, and so has its object, so that other lines of quite a different class have been built; some were built as substitutes for railway lines in districts where the traffic was unlikely to cover a railway's expenses; a few are simply tramways connecting neighbouring cities or serving suburban traffic.

The company does not work its own lines. Its object is to build them and lease them to working companies over which the "Ch. fer Vicinaux" still have some hold through the clauses of the working agreement. This is a remarkably good arrangement, as it does away with the errors due to the short-sighted policy of many a small company, and the whole of the country

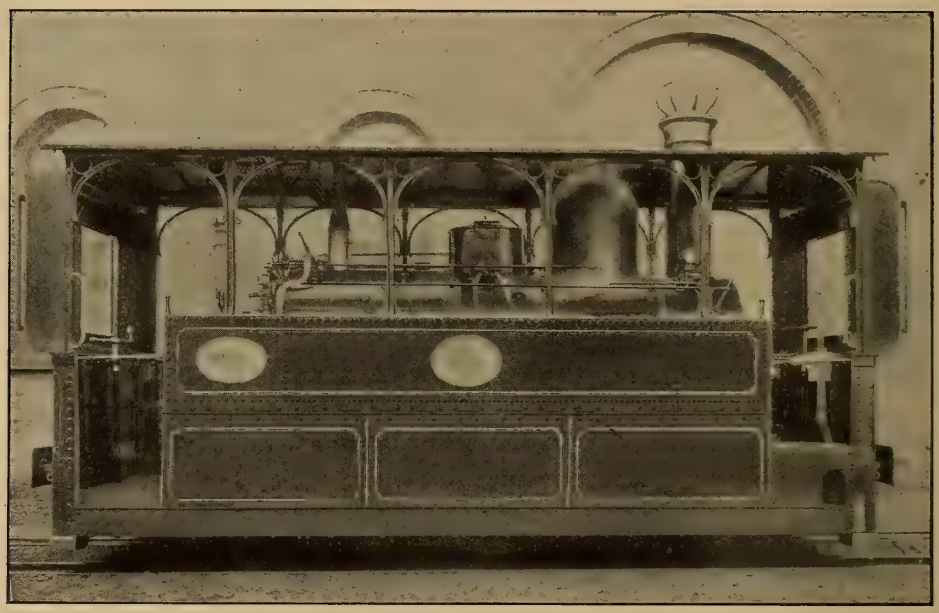
A MIXED TRAIN ON THE COMBINED RAILWAY SYSTEM

is well provided with useful lines, instead of companies building the most profitable ones only.

Each line has its own distinct capital, equal to the original outlay and divided into 1,000 francs (£40) shares. .

The shareholders are: the State, whose subscription may not exceed half the capital; the Province and the boroughs through which the line runs. The remaining shares, to an extent of 2 per cent., may be bought by the public. The State and the Province may pay off by means of ninety annuities. The State appoints half the directors and the president of the board, in exchange of a 3 per cent. guarantee of interest on the shares. The latest statistics (January 1, 1909) from which most of the items quoted are compiled show that the joint capital expenditure of the lines works out as follows:

FOUR-RAIL SYSTEM OF TRACK FOR THE LIGHT RAILWAY AND THE BELGIAN STATE RAILWAY



A STEAM LOCOMOTIVE OF THE BELGIAN SYSTEM, WITH THE MECHANISM COVERED

Capital expenditure, 267,421,000 francs (£10,611,587), out of which the State subscribes 112,702,000 francs (£4,472,302), 42.1 per cent.; the boroughs subscribe 75,826,000 francs (£3,008,968), 28.4 per cent.; the provinces subscribe 74,994,000 francs (£2,975,952), 28 per cent.; the public subscribes 3,899,000 francs (£154,722), 1.5 per cent.

The dividend was then 3.01, and has been falling pretty steadily since 1901, when it was 3.41.

The company's staff for getting out plans and estimates, working the new lines until they are leased, etc., is 512 only. But the company obliges all the working companies to insure their own staffs against all risks, to pay them a minimum daily salary and to grant them a pension after a certain number of years. They may not work them more than a certain number of hours daily.

Everyone being a shareholder, either directly or indirectly, through the medium of the borough or of the Province Councils, everyone's interest lies in building the lines as cheaply as possible. The boroughs usually manage to smooth over any difficulties that may arise, all the more so because expropriation always means further delay in the building.

The lines are laid along the high roads, which are remarkably straight in the northern part of the country, running as much as ten or fifteen miles without a curve. The land is then handed over to the company free of charge. When the roads are too narrow they are widened at the company's expense before the line is laid. In some cases, when the roads are too steep or curves too sharp, or for any other reason, the lines run over their own ground.

1,825 kilometers (1,140 miles) are laid along existing roads; 381 kilometers (238 miles) along widened roads; 1,118 kilometers (699 miles) upon private property. This, with 529 kilometers (331 miles) of sidings, etc., brings the total mileage up to 3,854 kilometers, or 2,409 miles.

These lines are laid to three gauges. The company's standard gauge is the meter gauge, to which are built 3,652 kilometers (2,283 miles) of line.

490 kilometers (306 miles) are laid to 1.067 m. gauge (3 feet 6 inches). This is for the lines in the northern part of the country, where junctions are made, or may be made eventually, with Dutch lines.

37 kilometers (23 miles) are laid to the normal railway gauge for through traffic, where such traffic bears no delay. Such is the case for the Groenendael Overyssche line, that carries nearly exclusively hothouse fruits and vegetables, a quantity of which finds its way to London, via Ostend and Tilbury.

There are 372 private sidings, aggregating another 116 kilometers (73 miles), 55 of which carry produce in large quantities, 316 connect factories with the system, and 1 the military camp of Brasschaet, near Antwerp.

There are 124 exchange stations with the State Railways, and, with a view to facilitating certain exchanges, 54 kilometers (34 miles) are laid with three or four rails, thus carrying mixed trains of various gauges.

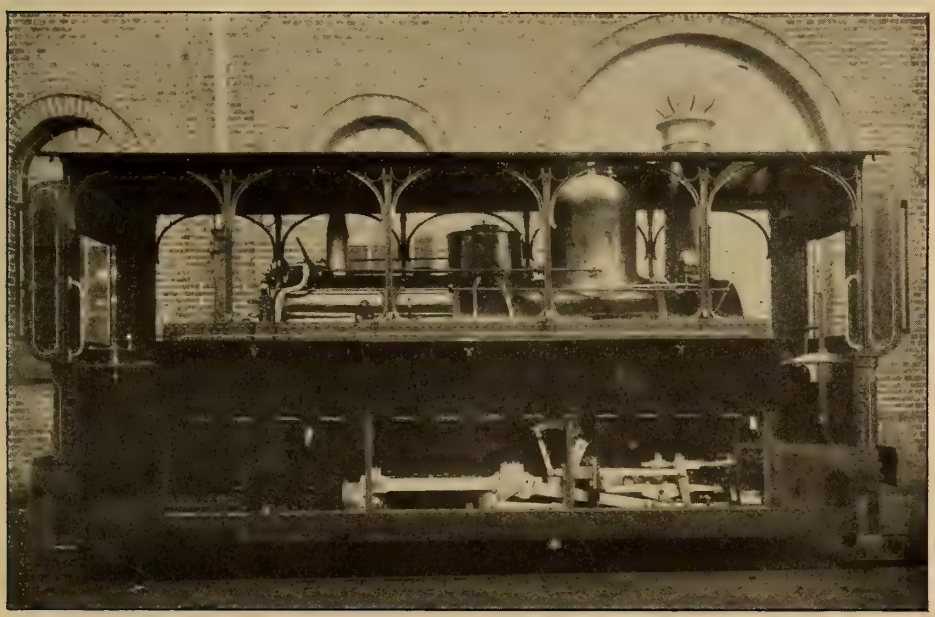
This is the existing system that grows yearly at the rate of some 200 kilometers (124 miles).

Besides the 3,336 kilometers (2,085 miles) open to traffic, 873 kilometers (546 miles) are building, or will be shortly, and bills have been applied for for another 1,972 kilometers (1,233 miles), bringing the total up to 6,151 kilometers (3,844 miles).

The proportion of light railways increases annually. As there are now 4,624 kilometers (2,891 miles) of normal railways, the proportion is now 91.8 per cent. of light railways.

There are 5.7 kilometers (3.3 miles) of light railways and 6.3 kilometers (3.8 miles) of normal railways per 10,000 inhabitants. There are 14.18 kilometers of light railways per 10,000 hectares—that is to say, 0.23 miles of line—per square mile; or, roughly speaking, 1-5 mile of light railway, besides an equal amount of ordinary lines.

The trains stop at frequent intervals, though there are but few stations. Tickets are purchased from the guard in the carriages, all of which are corridor cars provided with platforms at either end. There is



A STEAM LOCOMOTIVE WITH THE SCREEN RAISED, SHOWING THE CONNECTING RODS AND VALVE GEAR

A MIXED PASSENGER AND GOODS TRAIN IN BRUSSELS

ELECTRIC TRAMS IN BRUSSELS

always a café at each stopping place, the public room becoming the waiting room. This is much sought after, as most of the passengers have a drink before taking the train. Many are sufficiently patriotic (there is a tax on alcohol) to feel thirsty again when they alight.

On most lines passenger, goods and mixed trains are run; but the greater profits are derived from carrying passengers, about 13,385,538 francs (£53,117) out of a total of

Most of the rolling stock are four-wheeled vehicles with a very small wheelbase—5 feet 11½ inches or 8 feet. The remainder has either a particularly large one, the wheels having sufficient side play and radial boxes, or is provided with bogies.

The rolling stock comprises:

	Lines	Lines	Lines (On Order)	Lines (On Order)
	Steam	Elec.	Steam	Elec.
Locomotives	597	..	76	..
Steam cars	2	..	..	..
Electric cars	..	313	..	25
Closed cars	1,566	140	138	75
Open cars	..	97	..	10

A LIGHT STEAM LOCOMOTIVE BUILT BY THE ATELIERS METALLURGIQUES, BRUSSELS

18,983,143 francs (£75,329), 62.8 per cent. of the profits, therefore, accruing from passenger carriage and 37.2 per cent. from goods.

The length of the trains varies considerably, of course; they are often made up of seven or eight passenger coaches or of as many as a score of goods wagons; to these a composite coach—first, second and van—is usually added. As such long trains would be a great encumbrance inside large towns, they usually start from the outskirts.

Passenger and van	63	..	..	..
Vans	356	4	30	5
Open wagons	4,181	11	..	..
Closed wagons	857	1	372	..
Trucks	468	5	..	..
Various wagons	78	1	..	1
Mileage	1,885	125	....	....

This rolling stock cost about 41,468,320 francs (£164,557). On the steam-worked sections there are one locomotive per 5.273 kilometers (3.3 miles); one carriage per 8.852 kilometers (5.5 miles); one wagon per 0.564 kilometers (0.33 mile). On the electrically-worked portions, one

THE LIGHT RAILWAY STATION AT ANTWERP

electric car per 0.64 kilometers (0.4 mile); one trailer per 0.84 kilometer (0.53 mile).

There are two classes only, called first and second. The fares are as follows: For 24 kilometers (15 miles) in first class, 1/5*d.*; second class, 1/-. On the electrified portions in first class, 11*d.*; second class, 9½*d.* The State Railways charge in second class 1/4*d.*; in third class, 9½*d.*

The carriages are painted dark green, with the company's crest on the panels. The seats are plainly finished in varnished wood in second class and upholstered in red velvet in first.

Insufficient lighting is provided by two oil lamps in opposite corners. In winter, two seats are removed to make room for a stove—a most expensive proceeding, theoretically. In practice, the coal consumption is very low (as is the temperature), and a very small item indeed in the "expenses" column.

The locomotives have a curious appearance: the cab extends over the whole engine, giving it rather the appearance of a carriage with an engine inside. The large dome and safety valves are of polished brass, which, with their dark green coating and red buffer beam, gives them a neat appearance. They are double-ended; all the mechanism and handles are duplicated at either end. They are provided with a steam whistle for use in the country and a kind of trumpet for the towns; they have hand and steam brakes, but no continuous one. There are several types in use. The most usual has the following specifications:

Cylinders, 0.35 m. (13 6-8) diameter by 0.40 m. (15¾) stroke; wheels, 0.90 m. (2 feet 11¾)—0-6-0 type; total wheelbase, 2.50 m. (8 feet 3⅜ inches); length, 6.30 m. (20 feet 8 inches); width, 2.74 m. (9 feet ⅜ inch); height, 3.15 m. (10 feet 4 inches); weight, empty, 21½ tons; weight in working order, 27½ tons (all of which is available for adhesion). Water tanks carry

3,000 litres (660 gallons); the coal bunkers, 1 ton of coal; steam pressure, 10 atmospheres (143 pounds). There are 141 tubes of 0.045 m. (1 8-10 inches) diameter and 2.45 m. (8 feet ¼ inch) long between tube plates; heating surface, 53.55 sq. m. (576.42 square feet); grate area, 1.17 sq. m. (12.58 square feet).

The company owns, since a number of years, two steam rail motor cars of the Rowan type. They run on bogies; the engine portion is detachable. They have vertical boilers, with tubes in two directions, at right angles. Their diameter is larger nearer the grate than at the other end. There is a condensing apparatus at the upper part and steam heating throughout the car. However, this system has not proved very successful, and the two original vehicles have not been given any successors.

Laying the lines along the high roads reduces sub-grade work to a minimum. But the steepest gradients have been limited to 0.072 m. (1 in 13.8) for lines with passenger train services only. This is reached in Brussels and in Charleroi; lines with passenger and goods trains never have steeper gradients than 0.04 m. (1 in 25).

The sharpest curves have a 5-chains radius in the country, 1½ chains in town. There are two reasons for the difference: the average speed is 20 kilometers an hour (12½ miles), with a maximum of 40 kilometers (25 miles) in the country; and in town the trains are not supposed to run faster than horses do. The second reason is that in towns and villages streets meet at much sharper angles than roads do in the country.

Two patterns of Vignolle rails are in use. Both are 9 meters long (about 30 feet); they weigh, respectively, 15 and 12½ pounds per foot. They rest upon eight sleepers of creosoted oak, and are flush with the road on the outside; on the inside the greater part of the rail is above ground.

Transversal gutters are cut across the line every few yards for evacuating rain water and preventing cyclists or vehicles from following the track. Quenast is the usual ballast, covered over with ashes. It is a kind of porphyrite, found in quantities in the south of Brussels.

With a view to economy, cuttings and works of art have been avoided wherever it was possible to do so; the deepest cuttings are under 17 feet. Signaling is practically nonexistent. A few dangerous points alone, such as canal bridges, are protected by discs. Nearly the whole system is made up of single lines;

THE BRIDGE OVER THE SAMBRE AT NAMUR

24 kilometers (15 miles) only are laid with an up-and-down line. Collisions are exceptional and casualties few.

In 1908 there were

	Killed	Wounded
Passengers	9	72
Staff	2	10
Outsiders	42	40
	53	122

for 23,181,120 train-kilometers (14,488,200 train-miles).

Of this number, most "outsiders" were hurt owing to their own fault; they were mostly drunkards asleep across the track, unskilled drivers, etc.

Five passengers were killed and twelve wounded in getting off trains in motion.

These casualties are a pretty fair average for the past years and show a slight decrease yearly.

There are 3.65 killed and 8.41 wounded per 1,000,000 train-miles run.

The steam portions have cost 52,850 francs per kilometer (£3,354 per mile); the electric sections, 161,444 francs (£10,308 per mile).

The whole system has cost 62,796 francs per kilometer (£4,009 per mile).

The working expenses are 4,079 francs per kilometer (£260 per mile); the receipts, 5,905 francs per kilometer (£377 per mile).

The leases run indefinitely, but may be bought up by any of the subscribers if the borough and provincial councils think it fit. If a line does not cover its working expenses, the company may provide a further sum at its own risk, to be paid off with the first profits.

Curiously enough, if for three consecutive years a line is worked at a loss, or if for five years it brings in less than 50 per cent. of the capital's interest, the company may cease working it at all. Though this may seem odd at first sight, it comes well within the end the company was promoted to reach. It is to build lines of "public utility." It follows that

LIGHT RAILWAY STATION IN LOUVAIN

if a line does not cover working expenses the company's funds can be used to better purpose elsewhere.

It should be borne in mind that the company has not a light railways monopoly, though the great extension of its system, compared to that of the five private companies that own the seven remaining lines, has practically made it one. These are about 50 miles in length and join Noville Taviers to Embresin, through an agricultural district, Ans to Oreye, through a manufacturing one, or run to places in the vicinity of Brussels, Liège and Charleroi.

Such is the "National Company of Belgium Light Railways" after hardly more than twenty years' existence. But this great development has its drawbacks.

Most of the earlier lines connected a borough of some importance to a neighbouring railway station. Later on, looking at the line the other way about, it appeared as a bit of railway running from the station to nowhere in particular. It has since been extended to a further place, say another town, or else a station on some other line; instead of remaining a feeder to the principal railways it has become a railway in itself, and the drawbacks appear. These "vicinal" lines have quite overrun some parts of the country instead of the railways that should have been built, such as the Antwerp province and the coast districts. Now this is a pity, as they provide a hopelessly slow way of getting about, and their gauge being smaller than the railway one, goods must be unloaded at exchange stations.

Again, running along the roads is a splendid idea, as it allows numberless lines to be laid with small capital. But (here also there is a but) when passenger and goods traffics increase sufficiently, it may become advisable to turn the line into a normal railway, forming part of the general system. The fact that the company already runs a line between the two places will prevent its building another, as it would have to purchase the land, and will even bring it to oppose any scheme another company might promote for building a new line.

So, on the one hand these light railways must not take the place of normal ones; on the other, they should not act as tramways around large towns. The reason here is harder to find. It is a fact that where such lines exist complaints are frequent. It is not right that the State (the largest shareholder, be it remembered) should derive profits from working tramway lines around certain towns. Municipal or even County Council ownership are right and proper, and it is outside the scope of this article to compare the working of municipal tramways with that of private companies. But the State is here an outsider and has no direct interests at stake (if we except an electioneering one that should be non-existent), and tramways should not be built by the Light Railways Company as it exists; or, if built in towns that had none previously, they should be sold to a local company when occasion arises, and the money thus refunded put to some other use.

AN OLD-TIME CRANE

By F. G. Haldy

In an article upon cranes and hoisting machinery by Mr. J. F. Springer, published in the issue of this magazine for December, 1909, mention was made of the ancient type of crane operated by the power developed by men in treadmill wheels, referring to descriptions of such machines in Glynn's treatise on cranes. Glynn states that cranes of this kind were in use as late as the early part of the Nineteenth Century, but, as a matter of fact such a machine is in existence at the present time, and in active service. Mr. Haldy describes the old crane at Trier, or Treves, with illustrations made by himself, and this account forms an interesting contribution to mechanical history.—*The Editor.*

TREVES, or Trier, as it is known to the Germans, is said to be the oldest city in Germany, and lies in the beautiful valley of the Moselle River. It is rich in old and interesting edifices, especially the Roman ruins, such as the Basilica, now used as a cathedral, in which the holy coat is kept; the Porta Nigra, the Amphitheatre, the Roman Baths and the old bridge. Near the latter, situated on the bank of the Moselle, is an old crane, unique on account of the motive power employed.

Fig. 1 is an exterior view of this crane, showing also the old Roman bridge in the background, while Fig. 2 is an interior view showing a portion of one of the two tread wheels. Fig. 3 is a sketch made by the writer, the dimensions being roughly estimated, using the hand as a scale.

The booms, made of timber, braced with iron, revolve with the conical hood supported on a vertical mast, the top end of which is seen projecting above the hood, as seen in Fig. 1. This mast is turned by means of a pole strapped to it near the base, and has an iron pin inserted in the lower end, which latter is supported in a metal cup-shaped bearing, set in a cap stone, and shown in Figs. 2 and 3.

Strapped to the mast is a rectangular wooden frame, which supports two tread wheels carried on a horizontal wooden shaft with an iron pin 3 inches in diameter inserted in each end. On the inside face of each of the vertical members of the supporting frame is bolted a square metal plate, reinforcing the vertical members at the bearing for the shaft pins. The shaft is made of timber,

FIG. 1.—THE OLD CRANE AT TREVES

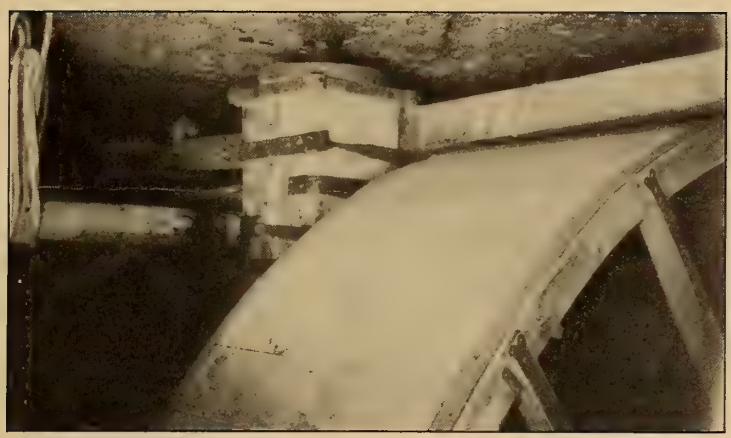


FIG. 2.—A PORTION OF THE TREADMILL OF THE OLD CRANE AT TREVES

15 inches square, rounded to 14 inches diameter, and faced with metal strips 3 feet long between the tread wheels, this portion serving as the drum for the 11-16-inch load chain. The method of strapping the frame and the pole to the mast is shown in Fig. 2.

The tread wheels are housed in a circular wall of masonry, reinforced by three buttresses, one of which is shown in Fig. 1. There is an upper bearing for the vertical mast situated near the small window to be seen in the roof just under the revolving hood.

The load is supported by a sling chain fastened to a single-sheave bottom block, through which passes the 11-16-inch load chain, one end

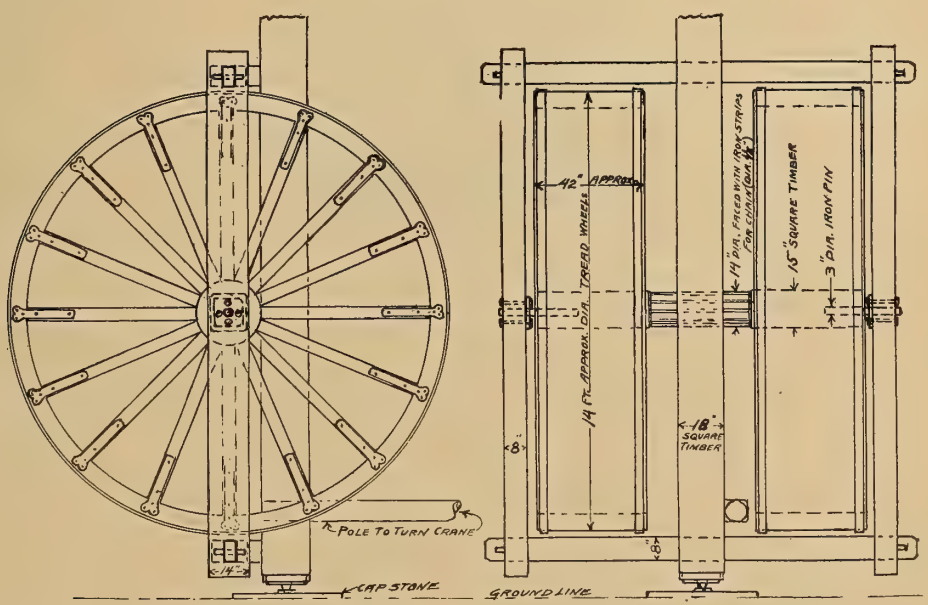


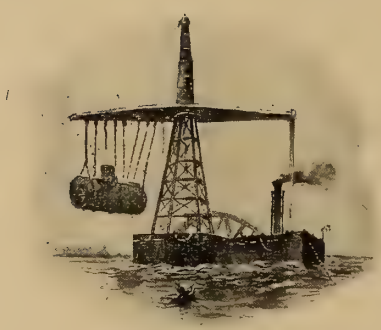
FIG. 3.—TREAD-WHEELS AND SWIVEL OF THE OLD CRANE AT TREVES

of the chain being anchored to the end of the boom, and the other end, passing over suitable guide sheaves, is fastened to the drum.

The power is obtained by workmen walking in the tread wheels, which have cleats fastened to the inner periphery to insure secure footing. The capacity of the crane is six tons. This machine is operated by the German Government for unloading boats bringing material for use in the arsenal, the building of which is shown on the upper terrace to the left of Fig. 1.

In some of the old cranes of this treadmill type the reverse movement was controlled by the men stepping backwards in the wheels, but with a heavy load it can be seen that loss of control might become serious. It was, therefore, arranged in most cases to use some sort of brake upon the outside of the wheel, this being easily arranged by applying a wooden bar underneath, this allowing the load to descend by gravity, held back by the brake, the men stepping backward as the direction of the wheels was reversed.

The writer was unable to obtain reliable information as to the precise age of this old crane, but from the appearance of the masonry it has probably been standing for more than a century.



Current Topics

THE question of electric traction on main-line railways is one which has been discussed at length many times, and the extent to which it may be adopted depends to a great extent upon local conditions.

In the last issue of this magazine the development of the electric locomotive was fully reviewed by Mr. Theodore Rich, and this is followed in the present number by a fully illustrated paper by Mr. Thompson, which is of especial interest as containing an account of the extent to which electric traction for railway service is beginning to make its way on the Continent. In the United States the development of electric traction on the New York Central, the New York, New Haven & Hartford and the Pennsylvania Railroads has been, in a large measure, the result of the changed conditions involved in the entrance into New York City. It is the electric locomotive which has made practicable the tunnels of the Pennsylvania Railroad, since steam locomotives would be unusable in such tubes, and it is the electric locomotive which is permitting the great extension of the entire terminal system of the other railways.

Railway engineers are divided as to the expediency of installing electric traction in the first instance and for an entire system, but experience in Switzerland and elsewhere may cause this opinion to be modified. A few years ago the objection urged against the use of electricity was the immense cost involved in the replacement of steam locomotives by the new machines; but there is every reason to believe that such a transformation would require about as long a period as would be demanded in the ordinary course of service with steam locomotives, anyhow, and little is heard of that argument at the present time. If passenger traffic alone was to be considered, it is probable that the question would be greatly simplified; but when the long haul of the heavy freight train is examined, the cost of the train-mile with the steam locomotive will be found hard to beat. Possibly the solution may be found in the entire separation of passenger and freight traffic, using different routes and systems of motive power. In any case, the result will be an evolution in which existing methods will be modified by environment and heredity in a manner already foreshadowed by what has thus far been effected in partial installations.

THE subject of heating buildings is a matter which will prove a big obstacle to the gas engine. A gas engine installation, properly installed and worked, will use less fuel than a steam plant of equal power. But when the heating of a building also enters into the problem before an engineer, a very different aspect appears on the scene. To heat a building will call for so much heat. How is this to be obtained? Much depends, of course, upon the amount of heat required for warming. If this is as much as or more than the heat in the exhaust of the steam engine required for power purposes, the economy of the steam engine will matter little, for no heat is wasted except by the boiler gases. Thus the problem resolves itself into a comparison of the heat lost up the chimney and the use of the waste heat of the gas engine; that is to say, the exhaust and the jacket heat. If the gas engine heat is enough to do the heating of the building, it may be worth while to use a gas engine and to heat air by means of its exhaust and jacket water and employ a fan system. Rules cannot be laid down to fit all cases. Each case must stand by itself, and be worked out for itself.

Let us suppose that in the exhaust of an engine there is 90 per cent. of the heat of, say, 70 per cent. of the fuel, the boiler efficiency being 70 per cent and the engine efficiency 10 per cent. Thus we have 63 per cent. of the fuel value to play with.

The gas engine uses, say, two-thirds of the fuel used by the engine and rejects three-fourths of this at the exhaust and jacket. The heat available is thus 75 per cent. of two-thirds, or 50 per cent. of the fuel consumption of the steam engine; that is to say, 80 per cent. of the available exhaust heat of the steam plant. It then only remains to consider if use can be made of this heat in a commercial manner to warrant the use of the gas engine for heating as well as power.

THE Pacific Coast of America, where fuel is dear, has naturally had its crop of wave motors, and very poor affairs they are said to be if their cost be compared with the results given by them.

There is probably much more commercial sense in the utilization of tide power, especially where the tidal range is high; but a study of existing tide mills is not conducive to a great belief in their commercial soundness, even with a tide of 40 to 50 feet. Tidal mills have been worked, and we believe still are worked, in France on the Lezardrieux River in Brittany, and the writer was inspected a small tide-worked corn mill in the Isle of Brehat, off the coast of that province. The means employed were very primitive—an undershot wheel working in a narrow slot formed in the wall of a pond help up at high tide behind an artificial dam thrown across a small inlet from the sea. When the tide went down below the base of the wheel the water was let upon the wheel, and turned it until the water was done or the tide returned. There was no benefit derived from the fall of the sea level below the bottom of the wheel.

The whole affair was very small in comparison with the outlay upon the enclosing dam, and the lesson taught by this mill was that to get any serious power from the tide it would be necessary to employ turbines running within, say, 10 feet of the lowest ebb tide, and a reservoir of water capable of being filled by neap tides up to a considerable depth. The proportion of the power apparently stored in an acre of water pond which can be got out of even a good turbine is quite small, and a still more awkward factor is the diurnal change of the time of the tide and its double daily occurrence.

The tidal mill is an attractive problem, but it will not bear close investigation as a big commercial affair unless there are some very exceptional natural circumstances.

LESTER PAIGE BRECKENRIDGE

A BIOGRAPHICAL SKETCH

IN the issue of this magazine for June, 1909, there appeared a portrait and biographical sketch of Professor Charles B. Richards, and this is fitly supplemented by the photograph which is reproduced this month of Professor Breckenridge, who succeeds to the chair of mechanical engineering of the Sheffield Scientific School of Yale University, from which Professor Richards has retired.

Lester Paige Breckenridge was born in 1858, at Meriden, Conn., and received his education at the Westfield High School and at the Sheffield Scientific School, from which latter he was graduated in 1881. After some years spent in practical engineering work he entered the field of education, becoming assistant to Dr. J. F. Klein in the department of mechanical engineering at Lehigh University, aiding his chief in the development of this strong feature of that institution. From Lehigh Professor Breckenridge went, after eight years of active service, to the Michigan Agricultural College, at Lansing, and in 1893 he accepted a similar position at the University of Illinois.

It is of the work of Professor Breckenridge at the University of Illinois that we desire especially to speak. During the sixteen years in which he filled the chair of mechanical engineering there grew up in connection with the College of Engineering a mechanical engineering laboratory, with very complete equipment, as well as machine shops, boiler house and machinery.

In connection with the activity thus developed, and as a direct result of his suggestions, the Engineering Experiment Station was established, and under his direction its excellent work has been accomplished.

The influence of such work upon the usefulness of the university as a school of mechanical engineering cannot be overestimated. Young men who really want to study an active profession naturally turn toward institutions where things are being done, and the laboratory and the workshop are not only important aids to lecture room and text-book, but often develop latent ability and interest which otherwise might lie dormant and unused.

It has sometimes been questioned whether it is desirable for a professor to engage in general engineering practice, or rather, if such activity is beneficial to his work with his students. In the case of Professor Breckenridge there can be no doubt as to the vast advantage which followed from intimate contact with external engineering affairs.

His work in testing steam machinery from prominent corporations, in the conduct of the fuel-testing work, in connection with the United States Geological Survey at the Louisiana Purchase Exposition, and in the investigation of smoke-prevention appliances for use with Illinois coals, all aided in bringing the educational engineering work at the university up to the latest modern standards.

When Professor Richards reached the retiring age and it became necessary to select a successor, it was to this active alumnus of Sheffield that Yale turned, and thus Professor Breckenridge has become leader where once he was student. How well this appointment has resulted

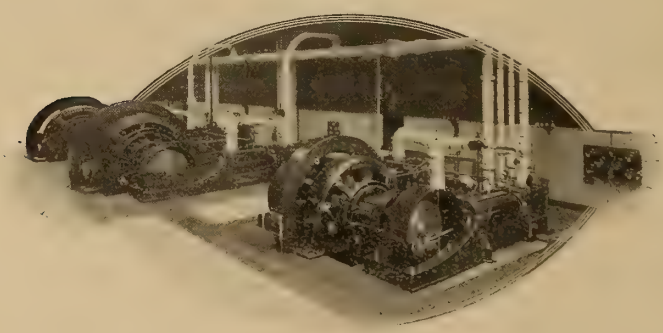
for his Alma Mater, we already see in the plans which have been made for the new mechanical laboratory, plans for which have recently been announced. Two graduates of Sheffield Scientific School, Mr. George G. Mason, of New York, and his brother, Mr. William S. Mason, of Evanston, Ill., both of the class of 1888, have given $250,000 for the construction and equipment of the laboratory, and the board of trustees has provided the land for the site.

The new laboratory will be located on Hillhouse avenue, nearly opposite the Leet Oliver Memorial Building. It will have a frontage of about 85 feet on Hillhouse avenue, extending back 200 feet, with a rear entrance on Temple street. It will be four stories in height. It will be constructed of Indiana limestone and brick and contain approximately 50,000 square feet of floor area and 880,000 cubic feet of space. The entire equipment will be new, and will consist of the most modern appliances for assisting the student in studying those fundamental principles of applied science which are closely related to mechanical engineering, such as the strength of materials, the combustion of fuel in furnaces and in internal-combustion engines, the making of steam in boilers of different types, the using of saturated and superheated steam in engines or steam turbines, the artificial production of cold, the production, transmission and use of compressed air, the pumping of water, the transmission of power, and the problems of heating and ventilation.

Besides furnishing a modern laboratory for undergraduate instruction, it is hoped that when it is suitably equipped it will be the means of encouraging graduates of the school to remain for four years of work, and, with the opportunities available, research work in engineering science may be carried forward by research fellows and members of the staff of the department.

It is expected that the plans will be ready so that work on the laboratory may be begun by next July and the building completed and equipped by June, 1911.

Professor Breckenridge has always been actively interested in the work of the American Society of Mechanical Engineers, of which he has been a member since 1890 and of which he was vice-president from 1907 to 1909.



Manufacturing News

The Oxygen-Acetylene Blowpipe in the Shop

FORMERLY the gas blowpipe, using oxygen and hydrogen, was considered as a laboratory appliance of a special kind, employed for the production of a very high temperature, or used in connection with a cylinder of lime for making the lime light in the projecting lantern.

The introduction of acetylene gas, and its use in the place of hydrogen in the blowpipe, has rendered the attainment of still higher temperatures practicable, and to-day the oxy-acetylene blowpipe is not only a scientific success, but has become a most valuable tool in the workshop.

The Davis-Bournonville Company, by whom the oxy-acetylene welding and cutting apparatus is manufactured, has met the practical and commercial points which are required to make the process available for machine-shop use, this including not only the production of the tool itself, but also the provision of a supply of the gases in a convenient form, together with the special appliances needed for different operations.

The oxy-acetylene blowpipe enables the operator to obtain temperatures exceeding 6,000 degrees Fahrenheit, a temperature capable of melting iron, steel, aluminum, brass, platinum, and, in fact, all metals used in the arts. This temperature is concentrated at the point of a flame, so that it may be directed exactly where its effect is desired, thus giving the operator an instrument having at the same time great power and a high degree of adaptability.

Broadly, there are two different uses to which such an instrument may be applied, one being the union of metals by fusing them together and the other the cutting of metallic pieces by fusing a narrow slit through their substance.

Autogenous welding, as the union of metals solely by the action of heat has been termed, is an operation of widespread usefulness. A few of these may be mentioned here, and many others will suggest themselves by analogy. Thus, the process may be employed for reclaiming light or heavy castings coming from the sand with blow-holes, sand holes, cold-shuts, lugs off, etc. Cracked or broken castings may be reclaimed by fusing the broken parts together, or by melting additional metal to the main piece. Pieces which must be in one piece, but which are difficult or impossible to mould, may be cast in parts and united by the oxy-acetylene torch; pipes may be repaired or flanges welded on, or any kind of an intricate connection made. In con-

REPAIRING A HEAVY CAST-IRON VALVE WITH THE DAVIS-BOURNONVILLE TORCH

nections which need not be broken the joint may be welded permanently after the parts have been placed in position. Different kinds of metal may be fused together, making a perfect union, the joint being undistinguishable. All of these applications follow from the fact that the temperature produced is so high that the particles of metal actually become united to each other and form one and the same piece.

A special use of the process consists in replacing material which has been removed in error. Thus, holes which have been drilled in the wrong places may be filled in and smoothed over solid; material which has been cut away may be replaced so that the operation may be repeated as may be desired. In short, the blowpipe torch forms the long-sought "putting-on tool" hitherto deemed impossible.

For cutting purposes the torch is of especial importance. Steel or wrought iron up to five or six inches thick can be cut through by the intense heat of the torch, the kerf being from one-eighth to one-fourth of an inch. Rivet heads may be quickly cut off and the shanks driven out, or parts of boilers, bridges, vessels, etc., cut apart and taken to pieces. The power of an intense heat, capable of immediately fusing any metal in use and yet controllable in the hands of a single operator and capable of being directed at a positive point, can perform operations formerly impossible, or practicable only with the expenditure of much time and money.

The Davis-Bournonville Company, 90 West street, New York, has exclusive rights of the Davis pressure generator for the production of acetylene which may be installed for work in manufacturing establishments, and it is also prepared to supply cylinders containing acetylene dissolved in acetone, thus providing the gas for portable work. The same firm manufactures pure oxygen by the chlorate of potash and manganese process and supplies it compressed in cylinders. The torch, the essential element in the successful operation of the process, is made after the French patents of A. Boas Rodrigues, of which the company controls the American patents, so that all the parts of a successful apparatus for autogenous welding, for cutting by heat, and for the various applications of the process are available.

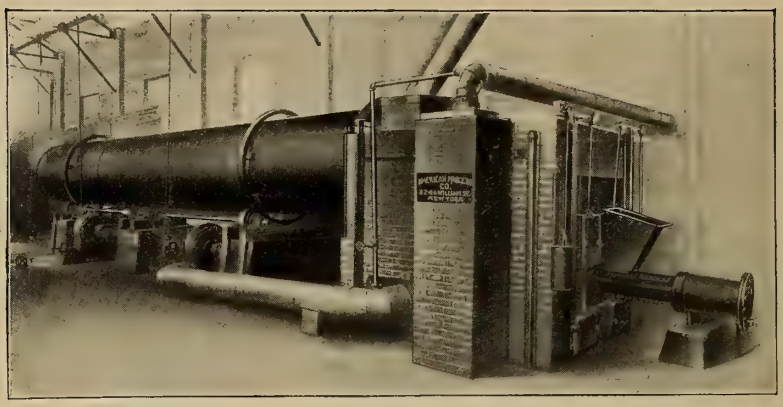
The cutting of steel or wrought iron (cast iron is unsuited for the operation) is effected in a manner which appears marvelous. The operation is effected by heating the metal at the first point of contact to a red colour, using the ordinary welding flame, and with this flame continued a jet of pure oxygen is turned on which unites with the carbon of the metal and disintegrates it with surprising rapidity. The cut is narrow and smooth, and there is no appreciable injury by oxidation. Since the cut can be made in any shape, at the immediate will of the operator, it is especially applicable for cutting irregular forms and fitting parts. Steel beams in structural work may be cut in place, or after they have been brought to the point where they are to be connected, while the hardest steel for burglar vaults can be readily cut through.

It will be understood that the installation of a process of such power and character requires the exercise of intelligence and experience, and that success demands that the purchaser and user shall have the benefit of the knowledge attained by the makers. The Davis-Bournonville Company has, therefore, established a demonstrating plant at Marion, N. J., where the operation of the process can be fully shown and applied. For information concerning this, and for handsomely illustrated catalogue and descriptive matter, all who are interested should communicate with the Davis-Bournonville Company, 90 West street, New York.

Personal

Mr. C. B. Humphrey closes a valuable service of fifteen years with the Westinghouse Electric & Manufacturing Company, during the last five years of which he was manager of the detail and supply sales department, to become vice-president and director of the White Investing Company, No. 43 Exchange place, New York City, which will negotiate the financing and development of enterprises based on natural resources and deal in bonds and securities. Among the interests of the concern are the Aguacate gold mines in Costa Rica, which are being developed and will be in operation in the near future. Mr. W. F. White, president of the company, who is a brother of J. G. White, was formerly manager of the Cincinnati Electric Company, and later vice-president of the North American Company. For a number of years Mr. Humphrey was district manager for the Westinghouse Company, with headquarters at Cincinnati, and was called to the home office in 1903 to take charge of the detail and supply department, which has grown to be an important factor in the Westinghouse business.

Professor H. H. Stoek, in charge of mining engineering at the University of Illinois, has been appointed by Governor Deneen as a member of the State Mining Commission, which has been constituted to formulate desirable legislation with reference to the mining industry, and to recommend the same to the Governor in anticipation of the next regular session of that body.



DIRECT-HEAT ROTARY DRYER. THE AMERICAN PROCESS COMPANY, NEW YORK

Direct-Heat Rotary Dryers

IN the course of numerous manufacturing operations it is necessary to extract the moisture from material before it is ready for further use, and different types of drying apparatus have been devised for this important operation. Thus, the by-products from chemical works and similar plants are nearly always charged with moisture; the same is true of packing-house, tankage, fish scrap and similar fertilizing material, while phosphate rock, glass sand, gypsum rock, etc., are examples of material for which drying apparatus is required.

For this purpose an improved direct-heat rotary dryer is made by the American Process Company, No. 68 William street, New York, this machine being constructed especially to develop large drying capacity and to stand heavy work. The general arrangement of these dryers is well shown in the illustration, the apparatus consisting of a rotary shell placed in an inclined position and arranged so that the wet material and the furnace gases enter it at the higher end. In the interior of the shell there is a shelf, which catches the material at the bottom and carries it around as it revolves. When the wet material is thus lifted nearly to the highest point of rotation it falls in a shower through the hot gases, this operation removing much of the moisture, the material falling to the bottom of the shell, to be again lifted to the top and again passed through the drying atmosphere. This operation continues until the material, in a dried condition, is discharged at the lower end of the shell, the inclined position, together with the action of the draft, carrying the material through the shell. This arrangement causes the wet material and the furnace gases to travel in the same direction, the highest temperature being in contact with the wettest material, a procedure theoretically and practically essential with the highest economy of fuel.

As shown in the illustration, the apparatus is constructed in a very substantial manner, and is capable of handling a large quantity of material of any kind, standing heavy wear and tear without injury.

The apparatus is also adapted for calcining, roasting, or driving off volatile matter from solids, and for such work the action is reversed, the material passing in the opposite direction to the furnace gases and being discharged at the furnace end. When the dryer is designed for removing the moisture from coal, the furnace is arranged with an air chamber between the combustion chamber and the shell. A forced-draught blast-pipe is branched to both the ash pit and the air chamber, the air supplied to these two points being regulated by blast gates, so that the

temperature of the gases entering the shell can be controlled. If the coal to be dried runs high in moisture the air chamber can be omitted.

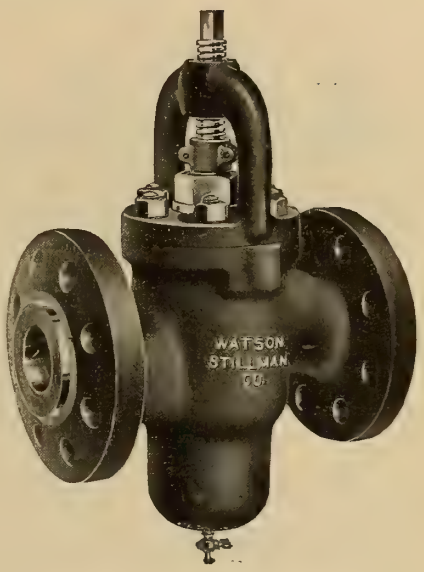
In designing these dryers the number of moving parts has been kept very few, and the construction is such that the wear is very small and is limited to parts which are readily repaired or replaced at moderate cost. The workings are all exposed, and thus open to inspection by the operator without taking him from other duties.

The influence of humidity upon manufacturing operations is only beginning to be properly appreciated, and there is little doubt that the use of properly designed dryers would greatly increase the efficiency of many operations. It is most important, however, that such apparatus should be constructed in accordance with correct principles, and be built in such a manner as to stand the severe working conditions to which it is necessarily subjected, and the desirability of consulting such experts as the American Process Company is evident in planning apparatus of this sort.

Special Hydraulic Valves

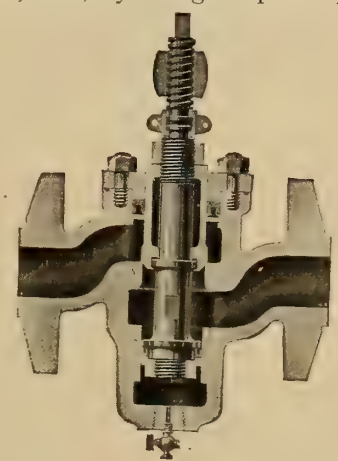
THE special types of hydraulic stop valve and check valve which we illustrate have recently been installed in one of the plants of the New York Edison Company, and are illustrative of the Edison Company's efforts to provide every possible protection against shutdowns.

Over a hundred of these valves, in 2-inch, 2½-inch and 4-inch sizes, are installed on the forced-feed lubricating system which serves the step bearings of the Curtis turbines. This lubricating system is under 1,500 pounds per square inch pressure, is provided with accumulators to deliver pressure in case of temporary failure or stopping of the pumps, and all joints in the lines are welded to



WATSON-STILLMAN HYDRAULIC STOP VALVE

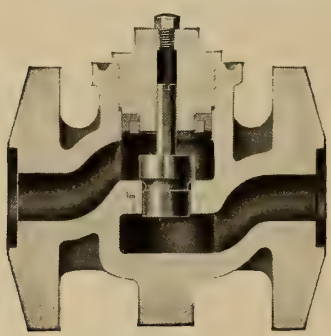
prevent failure. All parts are three or four times as heavy as ordinarily, and the bodies of the valves shown above are made of steel and extra heavy. Strength, however, was not the main question in discarding other valves on this service. It was found that ordinary rubber, hemp or leather packing would not stand up with oil and the unusually heavy pressure, but was subject to annoying blowouts. These troubles were overcome in the Watson-Stillman stop valve in two ways; first, by using a special pack-



SECTION OF HYDRAULIC STOP VALVE

WATSON-STILLMAN HYDRAULIC CHECK VALVE

ing which would not soften, but would retain its elasticity, and second, by a construction which would permit the system to be used even though a packing weakened. The improvement in the latter instance consists in the addition of the small, pressure-tight chamber under the end of the valve stem. When running under ordinary conditions, the small pet cock at the bottom is left open to act as tell-tale if a packing starts to leak. Should the packing leak, the



SECTION OF HYDRAULIC CHECK VALVE

pet cock is closed and the valve used until such a time as a repair may be conveniently made.

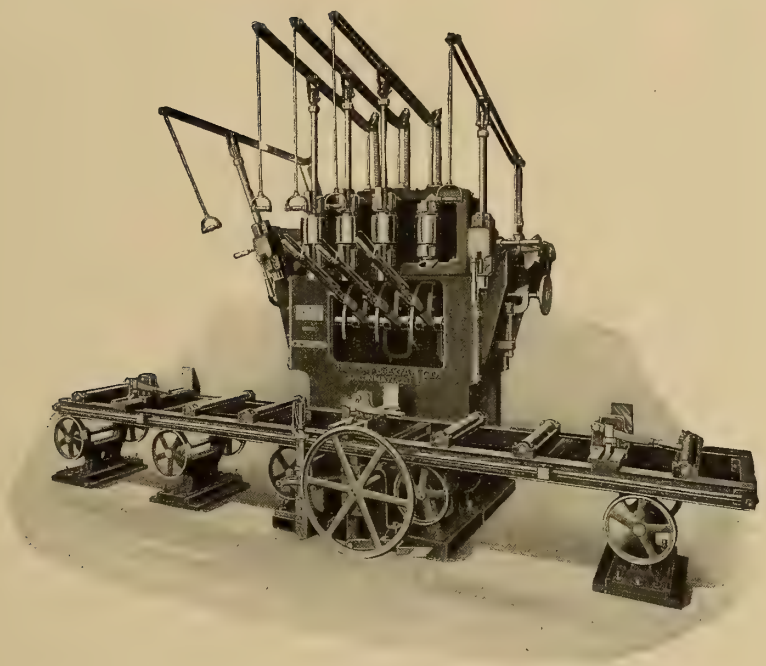
Both stop and check valves have seats of a special metal which is spun into place. The check valve stem is slotted, so that by removing the screw on top of the valve a screwdriver may be used to re-grind the valve seat.

These valves were made by the Watson-Stillman Company, of New York, who make a complete line of hydraulic pumps, piping, fittings and valves for forced-feed lubricating systems.

Trade Notes

The Ruggles-Coles Company, of 39 Courtlandt street, New York, reports the following recent sales of dryers for the purposes indicated: The Texas Company, Port Arthur, Tex., Fullers earth; Milan Mining & Milling Company, West Milan, N. H., iron pyrites; American Cyanamid Company, Baltimore, Md., cyanamid; Franklin Industrial Company, Warwick, Ohio, glass sand; International Harvester Company, Chicago, Ill., coal; Michigan Plaster Company, Wentworth, Mich., gypsum; Oklahoma Portland Cement Company, Ada, Okla., Coal, third order; Oklahoma Portland Cement Company, Ada, Okla., clinker, fourth order; Pennsylvania Cement Company, Bath Pa., rock, third order; Pennsylvania Cement Company, Bath, Pa., rock, fourth order; Standard Briquette Fuel Company, Kansas City, Mo., coal; Stone-Age Plaster Company, Newark, N. J., sand; Symington Company, T. H., Rochester, N. Y., coal; Toltec Portland Cement Company, Tula, Mexico, coal; United States Navy Department, Indian Head, Md., nitrate of soda; Waclark Titanite Explosive Company, Corry, Pa., nitrate of ammonia; Atlantic & Gulf Portland Cement Company, Ragland, Ala., coal; Columbia Chemical Company, Barberton, Ohio, coal.

The Raymond Concrete Pile Company, of New York and Chicago, has been awarded the contract for concrete piles and foundations of Stores 24 and 25, to be erected at Tompkinsville, S. I., for the American Bank & Trust Company. The Concrete Steel Company are the engineers for this work.



FAY & EGAN'S NO. 163 FIVE-SPINDLE VERTICAL CAR BORER

"Five Latest Car Shop Tools"

THE above title is the name of Fay & Egan's latest booklet which illustrates as many machines especially designed for car shops.

The No. 163 five-spindle vertical car borer shown here is one of the five. This machine is the outgrowth of many years' experience in the manufacture of car tools. It is especially designed for heavy work—column is cored casting of immense weight and with broad floor support.

Has capacity for timbers up to 14 inches by 15 inches, and is made with three, four or five spindles.

The table is made either stationary or traveling. The stationary table is 8 feet 11 inches long and has nine 5-inch rolls, four of which are power-driven. It has stops to regulate the length of mortise, and is operated by hand wheel, rack and pinion. The traveling table can be furnished any length desired. It is made of steel I-beams, and has automatic feed under instant control of the operator. It is provided with adjustable stops for regulating the distance between holes.

The spindles are 1 7/16 inches in diameter and carry pulleys 6½ by 6½ inches face, giving ample belt power, and can be adjusted in or out instantly by self-locking lever. The outside spindles angle 45 degrees inside and 30 degrees outside. They can be securely locked at any angle, and the frames on which they are mounted have vertical adjustments of 8 inches, each furnished with bushes to accommodate augers with 31/64 and ¾-inch shanks.

You are requested to write the manufacturers, 226-246 Front street, Cincinnati, Ohio, for their booklet, which they will send by return mail.

Modern Dryers

THE operation of drying, like many other industrial departments of work, has resulted in a development of devices, from the earliest and crudest forms to modern scientifically-designed machinery constructed especially for the purpose.

Certain materials, such as lumber, brick, and the like, are usually dried in heated chambers, the operation being an intermittent one, the chamber being filled and emptied repeatedly. Other materials, having a granulated or sub-divided form, may be passed through a machine continuously, and for such the modern dryer may be adapted, taking into account the general nature of the material from which the moisture is to be abstracted.

The modern dryer generally consists of an inclined cylindrical shell, so arranged that the material is fed continuously into the higher end and discharged at the lower, being brought into contact with heated surfaces or with hot gases during the transit, while currents of air are provided to carry off the evaporated moisture. Various arrangements of flanges or flights may be made inside of the drum to lift and agitate the material, and thus bring it thoroughly into contact with the drying surfaces or currents, the fundamental principle being the provision of ample opportunity for the heat to convert the moisture into vapour and to separate the vapour from the solid.

The great variety of material to be dried in different manufacturing operations demands the exercise of much skill, based upon knowledge acquired by long experience, and hence it is important that the advance of specialists in this department of engineering should be sought in the installation of such apparatus. The Ruggles-Coles Engineering Company, Hudson Terminal, New York, has for the past fifteen years been engaged in the design and installation of drying machinery of all kinds, and is thus prepared to advise as well as to construct and erect apparatus for every department of such work.

Materials which may be heated to a high temperature without injury can be dried by passing them through a cylinder in direct contact with the gases from a furnace, while others which cannot be thus treated require an apparatus with an inner flue for the hot gases, the material to be dried passing through the annular space between the two cylinders. Some substances require the use of but moderate temperatures, preventing the employment of the direct heat of furnace gases and demanding the use of steam pipes. In chemical works the nature of the material is often such that unsuitable apparatus will become clogged and choked, while in all kinds of drying work it is important that the highest degree of efficiency compatible with satisfactory results shall be attained.

The subject of fuel economy in the operation of drying apparatus is of much importance, and with a properly designed dryer the saving in fuel will, in a short time, pay for the entire cost.

The question of attendance is one which is often overlooked, and to this must be added the matter of the cost of repairs, this being closely connected with the convenience of access to the working parts.

It will be seen, therefore, that drying is by no means an operation to be conducted by inexperienced individuals, however competent they may be in general engineering work, and that the only way to secure satisfaction in the product and efficiency in the operation is to place the design and installation in the hands of experts, such as the Ruggles-Coles Engineering Company. This firm has prepared a handsomely illustrated catalogue, forming practically a treatise upon the subject of drying, and those who have drying of any kind included in their work should write for Catalogue F to the Ruggles-Coles Engineering Company, Hudson Terminal, New York.

Sheffield Gas Power Company

THE Sheffield Gas Power Company, of Kansas City, announces that it has purchased the entire plant and business of the former Weber Gas Engine Company, and that it is continuing the business, furnishing the entire line of Weber gas engines and producers to customers without any interruption to the trade.

The management of the business, both in the sales and factory departments, is in entirely new hands. George M. Hawes, the president of the company, is a graduate of the Massachusetts Institute of Technology, and has been interested in machinery and electrical work for a number of years, giving particular attention to central station power plants. He has also devoted much time to gas engine and producer design.

Freeman Field, vice-president and treasurer, has devoted the past twelve years exclusively to the gas engine business, both in the manufacturing and selling branches, and for the past seven years has been connected with the Olds Gas Power Company as general sales manager and Western manager.

W. H. Spiller, assistant manager, studied at Harvard and Brown Universities along the lines of electrical and mechanical engineering, and is thoroughly posted on power-plant installations, having installed both steam and gas power in many different industries.

During the past six years he has been affiliated with gas power interests in both the selling and manufacturing lines, and is especially fitted to supervise the works and see that all the numerous details of construction in high-grade gas-power plants are carried out with care and precision.

The American Waterworks Association will hold its thirtieth annual convention at New Orleans, La., next spring, the meetings being from April 26 to 30, 1910. Mr. J. M. Diven is secretary of the association.

Personal

Since the American Society of Mechanical Engineers has been in its new quarters in the United Engineering Building, in New York, the house committee has given attention, among other things, to the large and increasingly valuable collection of paintings which had been gathered in its former house. The oil paintings have been cleaned and renovated by Mr. Frank Goddard, well known as an eminent expert in this department of art work, the frames have been repaired and gilded, and the collection is now in excellent condition, forming a gallery of portraits of eminent engineers, including Watt, Stephenson, Newton, Ericsson, Holley, Worthington, Sweet, Holloway, Harrison, Fritz, Corliss, and others.

In order that the collection of paintings may be kept in first-class condition they have been placed in charge of Mr. Goddard, a practice which might be followed to advantage in other instances.

The Hill Clutch Company, of Cleveland, Ohio, manufacturers of power transmission machinery, announce the appointment of Mr. G. W. Hoffman as sales engineer in charge of their Chicago office, which is located at No. 610 Marquette Building.

Mr. W. L. Loveland, of the Allis-Chalmers Company, with which he has been associated for the past nineteen years, and, since 1904, manager of their mining machinery department, has accepted a position with the Mine & Smelter Supply Company as their general manager.

Mr. H. C. Holthoff, for many years identified with the mining branch of the Allis-Chalmers Company, and for the past two years manager of their Mexico office, will succeed Mr. Loveland as manager of the mining machinery department of the Allis-Chalmers Company and be located in Milwaukee.

THE LATEST CATALOGUES

Boat Motors

FAIRBANKS, MORSE & Co., New York. Catalogue No. 112A describes a large selection of marine engines of the one, two, three and four-cylinder type, from 2½ to 100 horse-power. Sizes, dimensions and code words for all engines are given in this list, together with illustrations of all the machines.

BUFFALO GASOLENE MOTOR COMPANY, Buffalo, N. Y. Handsomely illustrated book treating in a very exact way of a great variety of types. All desirable information about the requirements of boat motors, machine parts, code words and prices are to be found in this list.

Chucks

SKINNER CHUCK COMPANY, New Britain, Conn. Price list for 1909 describes in detail a full line of chucks manufactured by this company. The booklet contains prices and code words of all the appliances and their parts mentioned therein.

Gas Engines

AMERICAN STEEL & IRON COMPANY, Norwalk, Ohio. Catalogue B deals with the Davis valveless engine. This machine is built on the two-cycle principle, has an air-drying device, and does away with all mechanically-operated valves in the combustion chamber. The advantages of these features are described in detail, and the book contains also illustrations of all important and characteristic parts of the machine, of which various types are shown.

Furnaces

ROCKWELL FURNACE COMPANY, New York City. Illustrated catalogue describing with great care oil and gas-fired furnaces, for forging, heating and welding purposes, for end, centre and plate heating, as well as angle and rod heating. The booklet also deals with portable heaters, oil and gas-burners, blowers and oil pumps, tanks and meters.

Dryers

RUGGLES-COLES ENGINEERING COMPANY, New York. Catalogue F by this concern treats in detail of the requirements and the work of dryers. Five classes of dryers are described which are being built for a number of various materials, and tests of dryers given, as well as a list of users and recent buyers of the firm's machines. A good many appreciative letters are added to the text.

Gas and Gasoline Engines

DU BOIS IRON WORKS, Du Bois, Pa. The machines built by this company can be operated on natural, illuminating, producer gas, gasolene or alcohol, and are intended for power purposes as well as for electric lighting services. Code words and operating costs are also given.

ROCKFORD ENGINE WORKS, Rockford, Ill. Catalogue, describing and illustrating portable and stationary engines from 2 to 30 horse-power. Many types are shown and many applications named. Descriptions of grinding and pumping machinery are also given in this list.

INTERNATIONAL HARVESTER COMPANY OF AMERICA, Chicago, Ill. Catalogue giving description of all machines, their manufacturing and mechanisms. Portable engines, attachments for gas, combination gas and alcohol, as well as pumps, are dealt with and amply illustrated.

Gasoline Motors

FAIRBANKS, MORSE & Co., Chicago.—Catalogue No. 80 D, containing valuable data and information concerning the construction and applications of gasoline motors for domestic and farm service, and for all kinds of light work. The engines are adapted for pumping, for operating air compressors, mills, dynamos, saw benches, and similar service, and represent a most useful and reliable line of motors from 2 to 12 horse-power.

Joints

Moran Flexible Steam Joint Company, Louisville, Ky. Catalogue devoted to the subject of flexible joints for steam, air and gas; also, double flexible joints for either steam or liquids. The booklet describes and illustrates a great variety of applications of joints, such as for machine connections, rock drills, temporary steam lines, hoists; for testing purposes, pipe-laying, heating connections, loading and unloading tanks. It also deals with fillers and sprinklers.

Oil Engines

Remington Oil Engine Company, Stamford, Conn. This catalogue is devoted to the description and illustration of the kerosene stationary and marine engines built by the firm mentioned. The one, two and four-cylinder types are given consideration, and a table gives prices and code words of all the machines constructed by this company. Numerous testimonials close the booklet.

Oxy-Acetylene

Davis - Bournonville Company, New York. Handsomely illustrated booklet giving the descriptions of the torches manufactured by this company for welding and cutting metal by means of the gas mixture named above. Illustrations show repairs being done on heavy iron and brass work and the cutting effect of the respective devices. The book treats also of the generation and storing of acetylene and oxygene, and gives approximate prices of the work performed with the machines described.

Pyrometers

Bristol Company, Waterbury, Conn. Bulletin No. 108 contains the description of electric pyrometers for the especial use on hardening furnaces, in lead and barium baths, and besides diagrams explaining the method of applying these apparatus, illustrates a portable instrument of this type. Bulletin No. 115 covers pyrometers for annealing furnaces, which former are manufactured both for indicating and recording temperatures in the furnace.

Steam Engine Indicators

Trill Indicator Company, Corry, Pa. Attractive booklet on indicators for high-pressure and ammonia work, on the faultless reducing motion and the Trill planimeter. The causes of various curves are pointed out and a method given for drawing adiabatic and saturation curves. There is also a chapter on indicating gas engines, with discussions of faulty diagrams and a chapter on indicating compound engines and drawing combined cards.

Thermit

Goldschmidt Thermit Company, New York. This firm's quarterly publication, "Reactions," describes and illustrates in an interesting manner the varied use of thermit as a welding material. Its applications for welding rails and high-pressure pipes, and also its applicability for marine repairs are shown by a number of photos of this work.

Wire

Morgan Construction Company, Worcester, Mass.—Special catalogue devoted to machinery for use in the manufacture of steel, brass, copper, and bronze wire, including drawing frames, muffle and pot annealers, dry houses, cleaning cranes, galvanizing equipment, mill trucks, pointers, reels, etc. An excellent presentation of the products of one of the foremost houses in the world in this department of manufacture.

Turbine Blowers

L. J. Wing Manufacturing Company, New York. Bulletin No. 6 gives account of the Typhoon blower and its parts, operation and special features. Besides illustrations, the booklet contains curves and tables relating to pressure and economy of the blower.

Industrial Railways

WHEN railways were first employed they were used in the British collieries for the transportation of coal, the cars being drawn by animal power and the loads conveyed from the mines to the canal boats or other vessels which then formed the sole means of long-distance transport. The original use of the railway was thus of an industrial nature, and it was not until after the development of the steam locomotive, enabling the horse to be superseded by the locomotive, that the railroad track took the place of the canal for the distribution of heavy merchandise. The importance of this latter revolution was so great, and the transformation which it effected was so far-reaching, that for a long time the possibilities of the railway for internal transport in industrial and manufacturing establishments was overlooked, or rather overshadowed, by the greater successor.

The industrial railway, however, has regained its own, or rather, has created anew a field of usefulness by no means foreseen when the slight tramways of the Newcastle collieries were constructed. Instead of using light strips of plate iron, spiked down to wooden stringers, and built, each in the place where it was used, without regard to what had been done elsewhere, the modern manufacturer places in his works and throughout his entire establishment a railway which itself is a product of a highly organized system of manufacture, fully entitled to rank with the other tools and machines of which his equipment is formed.

The importance of this development of internal shop transport will be realized when it is remembered that the cost of handling work may, in many instances, exceed the cost of the machining operations which constitute its manufacture. The labour element in manufacturing costs is very generally the controlling one, and a large part of the labour in manufacturing is occupied in handling the parts which, after passing through the hands of the machinists, are gathered for erection and assembling.

A modern shop, intended for the manufacture of a special type of steam engine, was described by its designer as a series of buildings so arranged that pig-iron entered at one end and completed engines came out at the other. This gives a clear idea of the flow of the material through the series of machines, through the succession of operations, through the hands of the various mechanics, to the department whence the finished product is shipped away to the purchasers. To maintain this flow, to keep the machines supplied with parts upon which the higher-priced machinists expend their time, and to keep everything moving, means that the appliances for shop transport must form an integral part of the equipment if maximum efficiency is to be attained.

It avails little to have tools of the greatest speed, used in machines of high power and operated by skilled attendants, if there is delay and irregularity in the flow of material and parts of work through the establishment. The final efficiency of any series of operations is well known to be the continued product of the several efficiencies of them all, so that one operation of low efficiency may pull down very severely the good work which is being done elsewhere. By the use of a properly designed system of industrial railways the questions of transport and handling, usually one of the most infficient elements in shop work, may be raised to a level fully as efficient as the machining operations with which it is associated.

The industrial railway, like every other properly designed machine, not only does its work better than formerly effected by manual labour, but also relieves mankind from violent muscular effort, and replaces it by a mechanical appliance at once more efficient and reliable.

Hunt "Industrial" Railways

21 1-2 Inch Gauge

FOR MANUFACTURING ESTABLISHMENTS

Any Ordinary Workman Can Install It
It is the Simplest and Quickest Railway to Install

TRACK LAY-OUT IN OUR YARD BEFORE SHIPPING

Each lay-out of "Industrial" Railway track is carefully laid in exact position and fitted in our shops before being sent out. The switchings and crossings are firmly riveted to the cross-ties and are carefully marked so that when it is received it can be laid down correctly by an ordinary workman.

This system permits more work to be done in a given time, which means more contracts can be carried out in a year with the same number of men and same amount of capital. It is a labor saver in every sense of the word.

We publish a catalogue, "Industrial" Railways, and copy of this useful book will be sent if you are interested in reducing the cost of handling materials in your establishment.

C. W. HUNT COMPANY

ESTABLISHED 1872

West New Brighton, New York **New York City Office, 45 Broadway**

Variety in Hoisting Appliances

WHEN a burden is to be lifted the general idea connected with the job is its magnitude; a light article may be easily handled, a heavier one demands some special tackle and rigging for the purpose. Since the principal appliance for such work was formerly some form of rope tackle, using wooden blocks and having the same general arrangement as similar appliances on shipboard, operations of this sort usually fell into the hands of "riggers," men whose ideas upon this subject were naturally along the same lines as those of sailors. Even at the present time the handling of building material and the manipulation of burdens out of doors is conducted by the same class of workmen to a considerable extent, but this practice is gradually being superseded by the employment of more mechanical contrivances.

This change is largely due to the development of hoisting appliances for use in the machine shop, in manufacturing establishments and in warehouses, and to the ingenuity of modern inventors and designers applied to the various problems which have arisen in the course of the progress of modern engineering.

An important factor in this development of hoisting appliances was the perfection of the chain block. The original differential block, invented by the late Thomas A. Weston about fifty years ago, was a revelation to the mechanical world, offering, as it did, a light, convenient and very simple device which enabled a man to lift heavy weights and did not require him to hold anything to keep the burden from falling. This apparatus was followed by the production of the safety disc-clutch, also due to the same inventor, and enabling the manufacturers to produce a variety of winches, crabs and cranes, all of great convenience and excellent efficiency, and all giving the same essential control of the load, whether in motion or at rest.

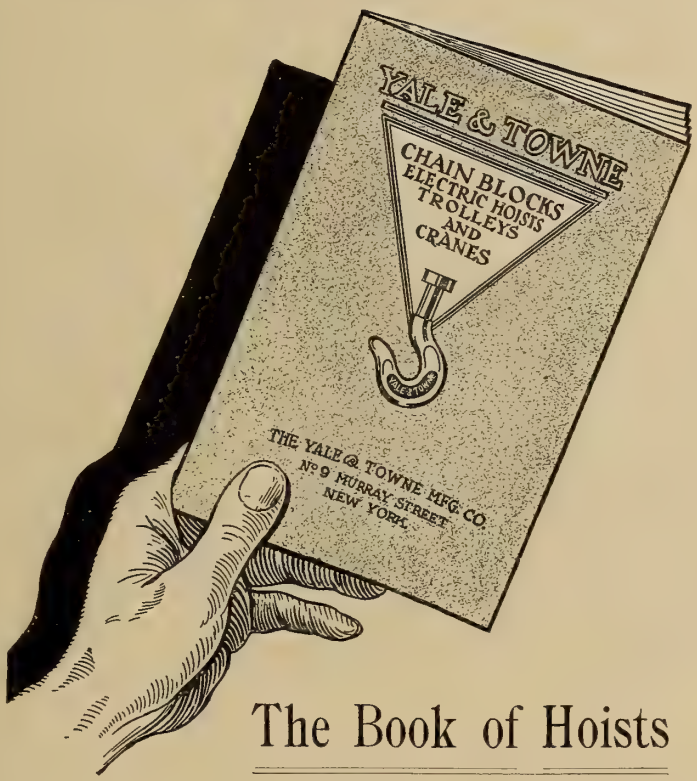
The differential block filled an important industrial position; but with the growing demand for more efficient appliances there was produced the Duplex and the Triplex blocks, chain hoists having equal convenience, far greater efficiency, and a more widely extended field of usefulness.

As these modern hoisting appliances came into use there was developed with them various forms of apparatus for including the operations of lateral conveying. The overhead tramrail, with its trolleys, switches and turnouts, provided means for handling material in three dimensions, giving vertical hoisting and lowering, by use of the chain hoist, and enabling the load thus sustained to be moved in any direction horizontally as well.

The development of electric power, and the general provision of electric current in shops and manufacturing establishments, naturally led to the addition of the electric motor to the hoist for situations where greater power and speed were demanded than could readily be effected by human effort, and thus the electric hoist was added to the list of specialized devices.

From these varied elements it is possible to combine the functions necessary for almost every department of work so that hand or power cranes may readily be made up by the use of the chain block or electric hoist, and practically all requirements efficiently met.

Thus we see how the simple operation of lifting heavy weights has led to the production of an extensive line of special appliances, each adapted to a wide variety of work and yet each having its own field of special usefulness. The old rope tackle, with its accompaniments of seamen's lore, and with its many inconveniences, is relegated back to its proper place on shipboard, and the modern mechanic, in handling his work, uses a machine which is in every way as scientific and as efficient as the machine tool before which he stands.



The Book of Hoists

Send for a copy of the new edition of our complete catalogue of hoisting apparatus which is now ready.

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Triplex Chain Blocks
Duplex Chain Blocks
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Motor Driven Trolleys
Crane Trolleys for Electric Hoists

The Yale & Towne Mfg. Co.

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Transmission Troubles

NEARLY every large manufacturing establishment has its department of power and plant, the portion of work including not only the care of the equipment and the generation of power, but also having in charge the general operation of the works, and thus dealing with the transmission of the power to every nook and corner of the place.

With the general replacement of manual operations by power-operated machinery, it will be realized that the successful conduct of a manufacturing establishment depends almost wholly upon the maintenance of the motive power. Not only must the "wheels go 'round," but they must be kept uniformly and continuously in motion. Any interruption blocks everything, causing certain delay; while in some departments of work, notably in the manufacture of iron or steel, the stoppage of the machinery for even a few minutes may cause metal to chill, material to be spoiled, and large expense to be involved.

In some departments of manufacture it is essential that the variations from the normal speed of the machinery is fatal to satisfactory work, this being the case especially in the textile manufactories; in other lines of work the transmission appliances are subjected to heavy and irregular shocks, and must be able to meet and sustain such stresses without failure.

In addition to such daily requirements as are indicated above, it is essential that the transmission system of an establishment shall be convenient so far as changes and extensions are concerned; it is often desirable to install new machinery at short notice, and the power must be got to such points of extension without serious derangement to the existing plant, and without requiring undue time. If repairs are necessary—a matter certain to arise sooner or later—the system should be so designed that the necessary work may be done with a maximum of speed and a minimum of expense.

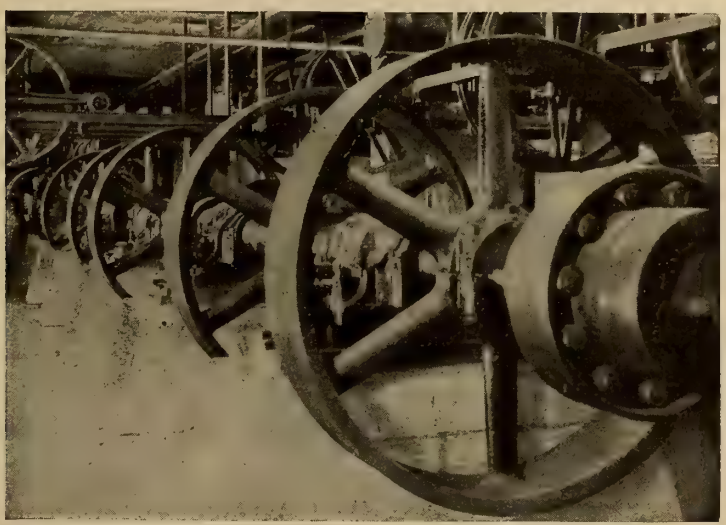
In the vital question of maintenance the arrangement of the transmission may play a most important part in the shop economy. Formerly it was understood that from 40 to 50 per cent. of the power generated by the engines and boilers was expended in getting the effort to the machinery which did the work, and a transmission using not more than 35 per cent. was considered very efficient. This is a matter which must necessarily be governed by local conditions; but in any case the efficiency of a transmission system depends very largely upon the manner in which it is installed, the methods of lubrication employed, and the extent to which proper alignment is maintained.

There are certain transmission troubles which can be avoided only by the exercise of continual vigilance on the part of the engineer by whom it is operated; but there are many difficulties which may be altogether eliminated by the use of the most modern appliances, installed by engineers who have a fund of broad experience for their guide. Mistakes will occur in the very best plans, but there is no excuse for the repetition of the same mistake. The man who has "been there before" has a vast advantage over the man of limited experience, and there is no department of work in which practical experience is of greater value than in the design and planning of a system for the transmission of power.

Future requirements may often have a controlling influence upon present work; the question of repairs, the provision for uninterrupted maintenance, the subject of lubrication—these are a number of divisions of the large question of power transmission which all go to make up a whole concerning which the broadest experience is essential for success.

The fundamental point is to have the work done right in the first place, and then most of the troubles will be eliminated.

DODGE



Beater Lineshaft in Paper Mill, Supported in Dodge Self-Oiling Bearings, and Carrying Heavy Dodge Split Iron Pulleys

If you are losing too much power between your prime mover and the machines —

If you are losing time and production on account of frequent shut-downs of your transmission equipment —

If you are wasting power by running idle equipment —

If you are wasting both power and oil, and, in addition, the wages of an oil patrolman, by using old-fashioned plain bearings —

In short, if you have transmission troubles of any kind, write us; tell us what they are; we can help you cut out the losses, and, perhaps, increase your production. We've done it for thousands of others. There is twenty-five years of "know how" at your service for the solution of any problems of power transmission.

DODGE MANUFACTURING CO.

Station K 11, Mishawaka, Indiana

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Overhead Electric Traction

WHEN the possibilities of electric power transmission were foreseen with respect to its applications to transportation, one of the first ideas suggested related to the transportation of burdens upon overhead rails. To this method the name "telpherage" was given by Professor Fleeming Jenkin, the word being made up from two Greek words, meaning to carry to a distance, the etymology being similar to that of the word telescope, a device for seeing at a distance, or the word telephone, to speak to a distance.

We have thus developed at the present time a complete department of industry, the carrying of burdens upon overhead rails, using the power of the electric motor; and this again has created a corresponding industry, the design and manufacture of special appliances for such work.

In the construction of a telpherage line there are several points to be considered. The line itself is usually made up of some form of structural steel shape, such as a T or I-beam, this being supported on a wooden stringer, or being made heavy enough to require no such support. The manner in which this runway is carried depends very much upon local conditions; indoors it may often be suspended from the beams of the building, while for outdoor lines various forms of trestles or bents are employed.

Upon such a runway the driving wheels of the telpher itself are supported, the car being suspended beneath, and containing a place for the operator, for the electric controllers and the general mechanism.

The electric power is applied to the wheels, the motors being geared to the axles, so that the whole forms a suspended electric car, taking its current from an electric wire, and capable of either carrying merchandise itself or of hauling a train of suspended trucks behind it.

It will be seen that such a system differs from the cableway type of conveyor and from the endless-belt conveyors in that it carries its own motive power with it, and thus forms an actual electric railway running through the air beneath the rail by which it is supported and along which it travels.

The commercial applications of the telpherage system are naturally varied and extensive; they include the transport of material anywhere where the runway can be erected, and they include speeds from 600 to 1,000 feet per minute. In most instances the load has to be raised from a lower point up to the telpher line, and after transport to the other end of the line it is deposited at the place of delivery, so that a complete telpher system involves both vertical and lateral handling of material or merchandise. If the amount of lift is small, it is readily effected by equipping the telpher with hand chain hoists; but for higher lifts the hoisting is readily effected by electric power, under control of the operator in the cage.

In the construction of a telpher line it is readily practicable for the runway to surmount grades, cross streams, follow curves, and cover ground otherwise difficult to be traversed. For handling and storing coal and for the removal of ashes the system is especially applicable, while for operation in connection with the loading and unloading of steamships, and with the operation of warehouses and railway terminals, it possesses a capacity and flexibility which demand careful attention.

In the installation of such a system it is always desirable to profit by the experience which has been gained in previous work. Both in the arrangement of the runway and in the selection of the general system of handling the material there are opportunities for doing the work right, and also for making serious blunders, if the work is committed to inexperienced hands.

Manufacturing News

The Railway Business Association

THE completion of the first year's work of the Railway Business Association calls for comment in this place, not only because of the excellent work which has been accomplished, but also by reason of the interest which its plans have caused in commercial, financial and legislative circles.

At the dinner given recently in New York upon the occasion of the first anniversary of the association, there were present, among others, such prominent financiers as Mr. J. Pierpont Morgan, Mr. J. Edward Simmons, Mr. Frank A. Vanderlip and Mr. James Speyer. Among railroad men may be mentioned Mr. W. C. Brown, president of the New York Central Lines; Mr. E. P. Ripley and Mr. J. W. Kendrick, of the Atchison, Topeka & Santa Fe Railroad, and Mr. W. G. Besler, vice-president of the American Railway Association. Commercial organizations were represented by Mr. Henry R. Towne, president of the Merchants' Association of New York; Mr. Martin A. Knapp, chairman of the Inter-State Commerce Commission; Mr. John Kirby, president of the National Association of Manufacturers; Mr. Frank W. Stevens, chairman of the New York Public Service Commission, Second District, and others; while manufacturing interests had abundant representation, including Mr. George Westinghouse, Mr. W. H. Marshall, president of the American Locomotive Company, and Mr. T. A. Griffin, president of the Griffin Wheel Company. It is of interest to note that among the speakers was the Hon. W. P. Hepburn, of Iowa, as well as former United States Senator John C. Spooner, of Wisconsin.

When such men as these are assembled to say what they think about the relations of the business interests of American railways to legislation, it is apparent that the subject is in appropriate hands.

There has been altogether too much feeling during late years that the railway interests of the country were a sort of public target, at which every one, in a legislature or out of one, might hurl stones with impunity, and that the public interests were to be served by taking the position that the railroads of the land—the real medium by which the resources of the United States have been developed—were a sort of common enemy, to be attacked, not only with license but for the public benefit.

During the one brief year of its existence the Railway Business Association has taught the people of the United States some well-needed les-

sons, showing them that the prosperity of the railroads lies at the bottom of all industrial and commercial development, and that the senseless policy of adverse legislation which has characterized certain law-making bodies is "worse than a crime—it is a blunder."

That this fact is appreciated by business men, by capitalists and by legislators of the highest class is well shown by the names above mentioned, names representing the controlling institutions and organizations in the business world, and names powerful in the inception and administration of legislative ideas.

It is not denied that proper regulation of all corporations, railways included, is a proper function of judicious government; but it is maintained that a system so closely allied to general business prosperity, the purchasing powers of which affect multitudes of great manufacturing enterprises, upon the success of which hangs the failure or prosperity of whole sections of the country; that this system shall not be made the butt of denunciations, threats and outcries, but that its regulation shall be approached with judicial moderation and solved with scientific accuracy.

The Railway Business Association has been in existence for one brief year, and during that time it has had much to do with the transformation of public and legislative opinion upon these points. Few institutions have done so much in so brief a time, and to few have such opportunities been given.

Large Self-Cooling Transformers

THE maximum size of a self-cooling transformer is limited by the amount of heat-radiating capacity for which the case can be designed. Standard cases with corrugated slides are regularly supplied with transformers up to about 600 or 700 KVA; but when this size was exceeded, weight and size of the case increased in a proportion which necessitated resorting to a method of

WESTINGHOUSE SELF-COOLING TRANSFORMER

getting the required radiating surface other than by merely greatening the size of the case.

The Westinghouse Electric & Manufacturing Company has recently developed a new type which overcomes the above difficulty and is capable of being designed for a larger radiating capacity than has ever been attempted for a self-cooling transformer. It consists of a plain boiler-iron case to the outside of which are welded a number of radiating tubes, which are in vertical position, and are given a 90-degree bend at the top and bottom where they enter the case. The construction of the case is strong enough to make its leaking or springing practically impossible. Because of the ease with which the tubes can be widely separated from one an-

other, the air circulates very freely among them, and the efficiency of the radiating surface is considerably higher than for the ordinary corrugated case.

There is a growing demand for large, self-cooled transformers in substations and other places where water for cooling purposes is either not available or else very costly, or where weather conditions are so severe that water-cooled transformers may give trouble, or where it is desirable to have as little attendance as possible.

The company has just built twelve 1,000-KVA, 100,000-volt transformers of this type, shown in the illustration, for the Southern Power Company; three of these transformers are for outdoor service and nine for indoor.

An Automatic Railway Cutting-off Saw

THE latest improved machine designed for cutting off large timbers and materials required in ship, bridge, car and mining construction work is shown in the illustration given below. The machine, which is made by J. A. Fay & Egan Company, Cincinnati, Ohio, is heavily and substantially constructed and capable of performing any work within its capacity to which it may be applied.

The carriage, which is mounted on planed ways on the frame, is moved forth and back by double rack and pinion driven by friction. By pressure upon the foot treadle, a regular-speed cutting stroke is effected, and the carriage returns as soon as the treadle is released.

The feed of the machine is driven by gears, and no chains or sprockets are used. The carriage is driven by cut rack and pinion, the latter being arranged at the centre of the travel of the carriage.

The machine is capable of cutting timbers up to 16 by 19 inches. The table has adjustable idler rollers, permitting the material to be easily moved across its surface.

A special feature of this machine lies in the traversing of the saw carriage by friction, so that the rate of advance always remains under the operator's control while the saw is running, and the movement of the carriage is automatically stopped in either direction.

The manufacturers, at 226-246 W. Front street, Cincinnati, Ohio, will be glad to render any further information to anyone interested.

The Professor and the Typewriter

A GOOD many years ago an American professor, who had learned the use of the typewriter for his own literary work, was making a visit to Germany, and took his machine with him. When, on his arrival at the German port, his belongings were examined by the customs inspector, the latter looked curiously at the typewriter—a device at that time not known in Germany—and asked the professor what that thing was.

"That!" said the professor, "that is a writing machine."

The inspector found nothing in the customs classifications about any such article, and so he was obliged to fall back upon something else.

"What is it made of?" said he.

AUTOMATIC CUTTING-OFF SAW

"Why," said the professor, "it is made partly of wood and partly of iron, and there is some india-rubber in it too."

This was rather indefinite, and so the inspector proceeded:

"Which material is principally used in its construction?"

The professor looked at the inspector, and said that it was principally made of small pieces of iron and steel.

Here was a clue! The examiner knew his schedule, and remembered that there was a rate for such materials, and hence the typewriter was passed as "iron in pieces"—that is, it was classified as *scrap-iron!*

Things have changed since that day, in more ways than one. The typewriter is better known in Germany, and has its place on the schedule. The old typewriter which the professor carried to Germany and back has literally become scrap-iron and gone long ago to the discard.

He still uses a machine, however, but one which could under no possible classification be relegated to such a name; for he uses a Monarch, and upon it he writes letters, magazine articles, books and records of his studies and investigations with an ease and satisfaction which long ago led him to abandon the use of the pen whenever the machine is within reach.

The qualities which render the Monarch typewriter so acceptable to the man who employs it for original composition make it doubly desirable for office and general use.

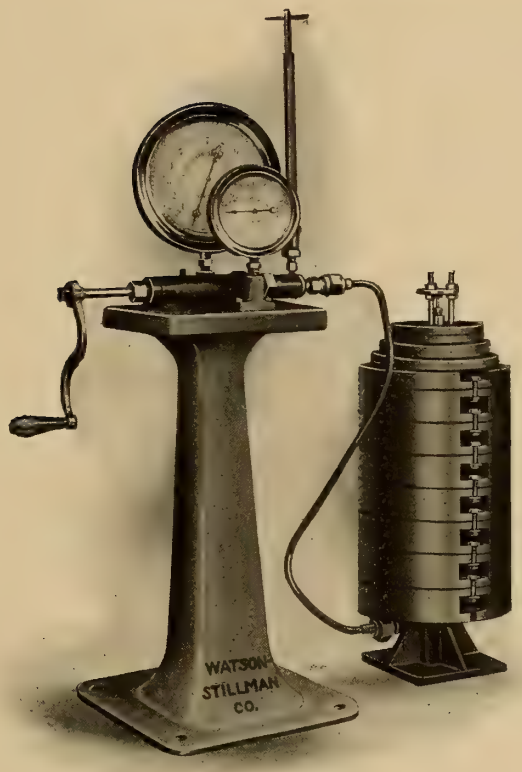
The light, elastic touch, which is so grateful to the individual whose current of original thought must not be interrupted, is particularly welcome to the stenographer with a book full of notes which must be transcribed before mail time. The perfectly visible page, almost an absolute necessity to the author, is equally important for the operator who so often has tabular and other formal matter to write; while the use of the tabulating attachment enables him to transfer to his page with ease matter which formerly gave him more trouble than was required to transcribe it with a pen.

One of the troubles with the old machine, the inaccessibility of the type for cleaning, causing him often to proceed with clogged and dirty letters because of the inconvenience of reaching the bars, is entirely absent with the new machine, since each letter is clearly placed before him, both visible and cleanable with a touch, and with no obstructing bars or impediments. When he reaches the bottom of the sheet on which he is writing, and has but a word or two to get on the next line, he no longer has to struggle with the lower edge of the paper, but finds a convenient little clamp which enables him to hold the sheet firmly until the last word is clearly written upon the extreme bottom of the sheet. If he misses a letter or a mark, the backspace lever enables him to return to the printing point with certainty and ease.

In short, he finds the Monarch the efficient companion of his daily work, the medium by which he expresses his thoughts, his records, and his instructions, and without which his work would be vastly inferior as to quality and greatly impeded in execution.

Improved Calibrating Apparatus for Hydraulic and Other High-Pressure Gauges

THE bursting of machine parts and fittings from excessive fluid pressure is usually accompanied by considerable danger, expense and delays for repairs. This is especially true with the extremely high working pressures under which liquids and air are often used. It is, therefore, quite important to know the pressure conditions within any apparatus using these sources of power, and for this reason the gauges should be calibrated at regular intervals. Under the higher hydraulic



WATSON-STILLMAN GAUGE-TESTING APPARATUS

pressures it is frequently the case that the same gauge will show different percentages of error at different pressure readings, and these can be compensated for in ascertaining the true pressure only by comparing with a "master gauge" of known accuracy or by loading with a known pressure.

The outfit which we illustrate performs these two functions of testing by comparison with a master gauge and of testing the accuracy of the master.

For the first, only the part on top of the stand is required. This consists primarily of a cross made of hydraulic bronze. The gauge being tested, which may register any pressures up to 16,000 pounds per square inch, and the master, are attached to the front and back ends of the cross respectively. At the left is a crank-operated screw displacement piston, by means of which the desired pressure may be produced within the pressure chamber. A suitable stuffing-box prevents leakage past the piston. To the right end is connected a stop valve and filling cylinder. This permits (1) some of the liquid to be withdrawn from the pressure chamber before removing the gauge being tested and (2) filling after a gauge is put on. There is thus no danger of spilling the oil.

For testing the master gauge, the special weight-loaded, hardened and ground steel piston and cylinder are attached at the right by means of flexible copper tubing, as shown. These parts are cut out by a stop valve when not testing the master. The cylinder is long enough to have

the centre of gravity of the weight below the centre of support. When the weights are revolved the friction due to lifting the weights is practically eliminated.

This apparatus is made by the Watson-Stillman Company, of New York.

The Dodge Manufacturing Company

SERVICE is one of the chief characteristics of the Dodge Manufacturing Company, power transmission engineers and manufacturers of the Dodge line of transmission machinery, Mishawaka, Ind. This is largely based upon the maintenance of large stores and warehouses in many of the principal cities of the country, in connection with expert engineering departments, which makes possible immediate deliveries and the solution of knotty transmission problems without delay.

From time to time the Dodge people have enlarged and extended this service until it now takes in nine points—Boston, New York, Brooklyn, Pittsburg, Philadelphia, Cincinnati, Chicago, St. Louis, and London, Eng. Announcement has just been made of the addition of Minneapolis, Minn., and Atlanta, Ga., to the list. These two branches will serve the twofold purpose of local stores and distributing stations for the Northwest and the Southland.

The Minneapolis store is located at 202-204 Third street, South, and the warehouse at 312 to 320 First street, North. The agency arrangement with the Minneapolis Steel & Machinery Company has been discontinued. Burke Richards, former resident salesman at Cleveland, Ohio, has been promoted to manager of the Minneapolis branch.

The Atlanta branch and warehouse is located at 54 Marietta street. S. L. Dickey, resident salesman at that place, has been appointed manager. No change has been made with any of the agency connections in the South.

News Items

Allis-Chalmers Company installed in New York the high-pressure system for suppressing fires not long ago, and this system having proved very satisfactory, a number of municipalities throughout the United States are now considering its introduction. This will undoubtedly result in a material reduction of losses from fire, which cause an annual damage of approximately $210,000,000. The system, whose capacity and efficiency greatly exceed the respective specifications, has stood the official test by an authority in a most satisfactory manner, and its application will no doubt increase considerably in the near future.

The contract for constructing the 500-foot reinforced concrete bulkhead and traveling-crane supports at Sparrow's Point, Baltimore, Md., for the Maryland Steel Company has been awarded to the Raymond Concrete Pile Company, of New York and Chicago, by whose engineering department the work was designed.

The executives of the Union Pacific Railroad Company are in a very appreciable manner keeping up the tendencies of the late Mr. Harriman. In a meeting of operating officials of the Union Pacific Railroad Company an understanding was come to with the purpose of the training of the company's employees for efficient service. The objects of the school to be founded by the company for its employees are three: to prepare prospective employees, to increase the employees' knowledge and efficiency, and to assist them to assume greater responsibilities. These objects are discussed in detail in Circular No. 24 of the company's office of the superintendent. While the entire idea of this scheme is good and practicable, one point deserves to be praised especially, viz., that an employee cannot even take a course for a position several grades higher than

that held by him before he has, in an examination, proved his ability and control of knowledge required for all the intermediate stadia. This warrants the good chance of an employee seeking advancement earnestly, and will greatly help the company in getting the kind of employees desired and needed.

The Westinghouse Electric & Manufacturing Company, East Pittsburg, Pa., has placed with the Raymond Concrete Pile Company, of New York and Chicago, the contract for concrete pile foundations for a new building.

The Allis-Chalmers Company, Milwaukee, Wis., has received an order from the Lackawanna Bridge Company for twenty-five 220-volt, direct-current Type "K" motors for its Buffalo plant. Allis-Chalmers Company received, in August, from the same company an order for a 200-kilowatt, direct-current, engine-type generator and twenty-one motors.

The United States Naval Department has recently awarded to the Allis-Chalmers Company, through its Washington office, a contract for three 100-K.W. (2,300-volt a. c.; 115-volt d. c.) motor-generator sets, two 25-K.W. exciter sets, and a twenty-seven panel switchboard. These machines are to be used in connection with improvements now being made at the Philadelphia Navy Yard.

The Forest Service of the United States Department of Agriculture in its Form 386 treats of the decay of wood; the following is cited from this publication:

"Wood decay is caused by fungus, a vegetable growth sometimes so small that it can be seen only with the microscope. Its roots or branches, like minute hairs, force their way into the wood tissues and absorb or eat away the solid parts. The collapse which results is called decay. Timber is artificially preserved by forcing into its cells and pores certain substances which prevent the growth of the fungi. As long as this substance is present in sufficient quantity the germs of decay—the threads and spores of the fungus—cannot enter, and the wood is preserved. This often means doubling and sometimes trebling the life of timber. * * * The lengthening of the life of timber means the saving of thousands of dollars annually through doing away with the heavy expense of labour and cost of material for renewals."

Personal

Dr. J. Berg, of Schenectady, N. Y., a graduate of the Royal Polytechnical Institute in Stockholm, who has been for the last seventeen years with the General Electric Company, now leaves this concern for the University of Illinois, at Urbana, Ill., whence he has received a call as Professor of Electrical Engineering. Dr. Berg takes the place of Professor Morgan Brooks, who is at present absent on leave for foreign study, but will, when he returns, continue as a professor in the department, as well as Dr. Berg.

Mr. E. C. Sornborger has been identified with Allis-Chalmers Company as a sales engineer in its pumping and hydraulic-turbine department. Mr. Sornborger has been an assistant engineer in the United States Navy for a number of years, and, besides this excellent engineering training, has gained commercial experience through his work with the Buffalo Steam Pump Company, the Gordon Steam Pump Company and the Snow Steam Pump Works. He still retains his interest in naval affairs, as commanding officer of a division of the Naval Militia of Buffalo.

We regret to note the death of Mr. Eli Emory Hendrick, which occurred recently. Mr. Hendrick was the president of the Hendrick Manufacturing Company, Carbondale, Pa., makers of perforated screens.

The Melville & Macalpine Reduction Gear

A VERY interesting account of the experiments upon the speed-reduction gear designed by Messrs. Melville & Macalpine for use with the marine steel turbine has been issued by Mr. George Westinghouse, this description and report covering investigations made at the works of the Westinghouse Machine Company during the present year, and being printed in the form of a handsome pamphlet, with illustrations and diagrams.

It has been well understood that the advantages, as to space and efficiency, which were anticipated in the application of the steam turbine to marine service have not been fully realized, mainly because of the disparity in the best rotative speeds for the turbines and the propellers. The De Laval turbine employed spiral gearing for the reduction of its speed to a practicable limit, but only for moderate powers, and it was considered impracticable to use such a method for machinery delivering several thousand horse-power, such as would be necessary for marine service, both on account of the mechanical difficulties connected with the construction of the apparatus and because of the supposed impossibility of maintaining proper alignment and distance relation between the pinions and gear wheels.

Rear-Admiral Melville and his associate, Mr. John H. Macalpine, have been endeavoring to solve this problem, and the pamphlet published by Mr. Westinghouse gives the result of tests upon the mechanism which they have designed, this covering investigations upon a gearing system transmitting about 6,000 horse-power, at a reduction of 5 to 1, and a speed of 1,500 revolutions per minute on the turbine shaft.

This transmission involved the use of spiral gearing of comparatively fine pitch and of wide face, the gears being of 1¼-inch pitch and 176 teeth, and the pinions have 35 teeth. Two pairs of gears and pinions are used, with opposite angles to the helices, in order to eliminate end thrust. The important and novel element in the apparatus, however, lies in the construction of the so-called "floating frame" in which the pinions are carried, this being arranged so as to be supported upon an I-beam which permits a certain limited degree of flexure to allow the pinions to adjust themselves, while at the same time the pinion-shaft is connected to the turbine by a peculiar form of coupling which permits end play to the pinion-shaft for similar self-adjustment.

In order to carry out the tests upon the apparatus as constructed at the works of the Westinghouse Machine Company, it was necessary to construct a hydraulic absorption dynamometer capable of determining up to 6,000 horse-power, and not the least interesting portion of the pamphlet relates to the design and construction of this important element in the work.

The report of the tests, made by Mr. H. E. Longwell, as consulting engineer, and witnessed by Commander R. S. Griffin, U. S. N., and Lieutenant-Commander U. T. Holmes, U.S.N., specially designed for this purpose by the Bureau of Steam Engineering of the United States Navy, shows that the system operated satisfactorily, with an efficiency of 98.5 per cent., the load of over 6,000 horse-power being limited only by the capacity of the turbine, and the endurance test lasting, in one case, from 3.15 P. M. on Saturday until 7.15 A. M. on the following Monday.

Commenting on these facts, Mr. Westinghouse proceeds:

"The United States Government has lately awarded contracts for two new battleships, to be equipped with steam turbines. These battleships are to have a speed of 20½ knots, which will require in round numbers 28,000 shaft-horse-power. With 55 per cent. propeller efficiency the

effective propelling power will be about 15,400 horse-power. With the 65 per cent. propeller efficiency that is easily possible with the reduction gear and a propeller at a lower speed of revolution, this same propelling power would require less than 24,000 horse-power on the shaft. The average steam consumption guaranteed at full power is about 14½ pounds per shaft-horse-power. With the better steam economy of the high-speed turbine, the boiler capacity required would be reduced fully one-third. With the same bunker capacity, the radius of action would be enormously increased.

"If the same boiler equipment as is now proposed were maintained, there would still be a saving in weight of over 250 tons, or approximately one-eighth of the total penalty weight of the machinery in each ship, resulting solely from the substitution of the high-speed turbine and reduction gear for the more cumbersome slow-speed, direct-connected machine. At the same time, by reason of the well-known overload capacity of a liberally proportioned turbine, there would be available a surplus power of about 50 per cent., which should make possible an emergency speed of nearly 3 knots in excess of that called for in the specifications.

"Furthermore, the three independent shafts, each with its own self-contained turbines for going ahead and astern, would give the excellent manœuvering qualities which are admittedly lacking in vessels with the present conventional turbine equipment.

"The certainty with which the floating-frame of the Melville & Macalpine reduction gear operates to maintain an evenness of tooth-pressure and the limitation of the maximum pressure to 450 pounds per inch of tooth-contact with a load of 6,000 horse-power, coupled with a large factor of safety, at once remove this invention from an experimental to a commercial apparatus."

Railway Developments in Siberia

IN the article on Siberia, by Mr. Henry G. Read, published in this magazine in the September issue of this year, mention was made of a number of railway projects which were yet under consideration.

Thus, the projected extension of the Ekaterinburg - Tiumen Railway line has been before a committee of the Duma, whose decision recommending that this extension should run from Tiumen to Omsk has been accepted by the Duma and since confirmed by the Russian ministry, all having decided that this route is, from every commercial and rational point of view, the only route to give the best results, and preliminary steps are now being taken to make a commencement on the line early in the spring of next year.

The further extension of this branch line from Omsk to the South, by way of Pavlodar to Semipalatinsk, may possibly be taken in hand by private enterprise; it is proposed to run a branch line of this extension from Pavlodar eastwards to Barnaul to join up to the projected branch from the main trunk line through Nerchinsk to that town; eventually the town of Semipalatinsk will undoubtedly be linked up westwards to the Tashkent line. The commercial importance of the Omsk - Pavlodar - Semipalantisk and Pavlodar - Barnaul portions of this projected extension cannot well be exaggerated. Once this set of lines are in being and working order, the prosperity of the whole region feeding to them will increase tenfold; not only this, the immense benefit to the main trunk line of the great Siberian railway by having an alternate route by these lines through Omsk and Tiumen, to relieve the ever-increasing congestion of goods traffic on their main line, must not be overlooked, for even if these lines are not their own property for a time, the relief of congestion will prove of great value in itself and they will lose nothing from a pecuniary point of view.

THE LATEST CATALOGUES

Acetylene Light

ALEXANDER MILBURN COMPANY, Baltimore, Md. The illustrated booklet given out by this firm treats of the advantages of the Milburn light. This light has been successfully applied by a large number of contractors and industrial corporations, by the navies of most European Powers, by railways, for dockyards, lighthouses, etc. The apparatus made by this firm are of very simple and durable construction, and the cost of 5,000 candle-power for an hour is six cents. The catalogue contains prices and code-words, and also a long list of users of the light.

Concrete Constructions

VULCANITE PORTLAND CEMENT COMPANY, New York and Philadelphia, have issued an attractive booklet, No. 8, which covers the building of monolithic concrete constructions. Description and illustration show strength and beauty of a building erected by modern architects with the use of none but the best of material.

Gear-Cutting Machines

NEWARK GEAR-CUTTING MACHINES COMPANY, Newark, N. J. In a handsomely illustrated catalogue this company describes its high-grade gear-cutting machinery. While some of these machines are designed for spur-gear cutting only, several of them can be used for bevel, skew and face-gear cutting as well. All of these machines are automatically operated—i. e., after once being started they require no attention until the gear is finished. This enables one operator to attend to several machines and do other work besides. Another characteristic of the Newark machines is their accurately-working indexing mechanism, which is self-protecting and prevents damage if the rim or lug should bind against the rim rest.

Machinery

WATERBURY-FARREL FOUNDRY & MACHINE COMPANY, Waterbury, Conn. Catalogue for 1910 describing a large assortment of machinery, which includes butt, rod, tube, cartridge, sheet-metal and hydraulic machinery; single-acting pillar presses, double-acting power presses and drop presses; hammers, shears, slitters, etc. Most of these machines are also in detail dealt with in special catalogues of the respective machinery, which can be had on application.

Sawing Machinery

NEW BRITAIN MACHINE COMPANY, New Britain, Conn. The new band-saw filer of this concern is guided mechanically in a horizontal direction, and the operator's action is reduced to watching that the file goes square across. This removes all difficulties growing out of hand operation. A saw sharpened by means of this machine will stay sharp longer than if filed by hand.

The New Britain dado machine helps greatly in reducing the costs on window frames. This machine is constructed with the object of cutting both dadoes on one stile at the same instant. At a stroke the labour on a pair of stiles is cut down three-fourths (of the labour needed before), and, if one stile is cut right, the mate is bound to match it. The machine is easy to adjust, rapid in operation, and quickly proves itself to be a money-saver. It can cut any wood, hard or soft, and will always turn out equally good work.

Motor-Driven Air Compressors

GENERAL ELECTRIC COMPANY, New York. Bulletin No. 4,699 treating on the geared type of the above-named compressors. The construction of these machines is illustrated, their operations described, and a table of dimensions, weights, speeds and capacities of the three types described is added to the text.

Jet Apparatus

SCHUTTE & KOERTING COMPANY, Philadelphia, Pa. Catalogue 2, Section R, deals with the Koerting deep-well water-jet pump, which works on the principle of the sucking effect of a swift current of water. This machine has no moving parts, requires very little space, and is capable of emptying completely any well or space filled with water without bringing the latter in contact with air, thereby avoiding oxidation. Section M describes the water-jet eductors built for use in mines, tunnels, and so forth. Here a high-pressure jet lifts water from further down, and all the water is discharged at some medium level, either to a pumping machine or, through cuttings in the ground, down a hillside. This machine, too, unites efficiency and small space, together with the positiveness of working on account of the simple and solid construction of the apparatus.

Refuse Destructor

POWER SPECIALTY COMPANY, New York City. Bulletin 101 and 102 of this concern give description and illustration of the "Heenan" refuse destructor. This furnace is designed for the purposes of destroying city refuse and to utilize the heat yielded thereby for municipal purposes, such as street illumination or running the waterworks, including the average amount of pumping. The destructors of this company are guaranteed against smell, smoke, dust and other nuisances, and can, therefore, be erected in the heart of a city which wants to destroy and at the same time utilize its refuse. One of these destructors has been successfully installed in the Borough of Richmond, New York City.

Drops and Drop Presses

WATERBURY-FARREL FOUNDRY & MACHINE COMPANY, Waterbury, Conn. Catalogue D of this firm is devoted to the description of machinery mentioned above, and also of forging and stamping machines. Drops of all sizes are illustrated, with hammer weights ranging from 35 to 1,200 pounds. All details and dimensions are given; prices will be quoted on addressing the company.

Thermit

GOLDSCHMIDT THERMIT COMPANY, New York, N. Y., and San Francisco, Cal. The booklet, "The Thermit Welding Process," is devoted to the application of thermit welding for steamship and railroad repairs. Numerous illustrations show clearly this system of repairing damages in one-seventh of the time required for their being done in repair shops and docks. The operation of thermit is shown and illustrated. In "Instructions for the Railroad Shops" detailed information, as indicated in the title, is given; also, prices of materials and appliances needed for this process.

Noiseless Pinions

NEW PROCESS RAW HIDE COMPANY, Syracuse, N. Y. The catalogue of this firm deals with the New Process noiseless pinions, their making and their advantages. The rawhide pinion can be well used for hard service, such as in engines, cranes, machine tools, automobiles, electric railway motors, etc. While their main advantage lies in their noiselessness, they have others too, viz., that they need no lubrication, and that a metal gear running against a rawhide pinion is used up much less than if running against metal. The booklet contains also a complete price list of all pinions made by the company, and of finished blanks of New Process rawhide.

Cement Sidewalk Paving

VULCANITE PORTLAND CEMENT COMPANY, New York. Pamphlet No. 7 contains valuable suggestions regarding the construction of sidewalks. This clear and detailed article will be of use to everybody connected with the work dealt with.

Electric Hoists

WHEN electricity was at first applied to the driving of machinery, there was much hesitation about using the electric motor in exposed situations and in placing what was then thought to be a rather fragile machine in the hands of labouring men. The dynamo could be kept indoors and placed in charge of an engineer who was familiar with the care of machinery, but if the motor was to be applied to rough outdoor work it was felt that improvements would have to be made.

There is a story told of the placing of an electrically-driven winch upon the deck of a vessel, and, after it was installed and the builder appeared to make demonstration of its operation, the captain ordered the full force of the fire-hose jet to be directed upon the machine. To the objections of the manufacturer, the old sea dog remarked that the winch would have to stand worse wettings than that in actual service, and that if it could not stand such a simple test it was out of place on board ship.

Things have changed since that time. Builders of electric hoists, winches and windlasses know that there are worse things than wet to be contended with. The hoist must be prepared to stand exposure to the weather and to operate successfully in the midst of dust, dirt and ashes. Both electrical and mechanical engineers have risen to the solution of the question, and to-day the electrically-driven hoist is used in practically every location where steam or compressed air was formerly employed.

The late Clerk Maxwell, when he heard of the incident of operating a dynamo as a motor by the electric current, immediately stated that it would prove to be the greatest mechanical development of the nineteenth century. To-day there is little doubt that this prediction might have been extended well into the twentieth century, since the application of electricity for the delivery of power into all places where work is performed is continually increasing.

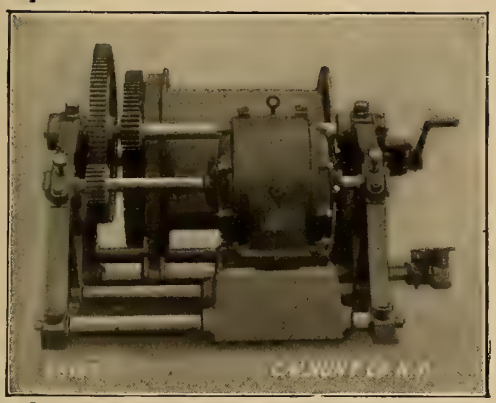
Electric power has a number of advantages apart from the ease and simplicity which must always accompany a form of energy which may be transmitted in almost unlimited quantities anywhere where a wire can be run. Steam power involves the maintenance of fire and boiler pressure near the spot, even when no work is being performed, and the cost often runs on even when little or no work is being done. With electric power, the consumption of current goes on only when work is being performed, and the moment the switch is turned over the current cost is stopped. Even though the dynamos at the central station may be running, the current is not being wasted, but is stored to help over the peak of the load which may be coming later.

Apart from the necessity of providing electric machinery which shall be "fool-proof," as it has been termed, it is essential that apparatus for such service shall be of the highest class, so far as its mechanical construction is concerned. Formerly it was thought sufficient to make a hoist with cast gears of the commonest character, and the parts of each machine were put together without regard to any others of the same kind and without any comparison, so far as workmanship is considered, with the care which is given to the better class of machinery.

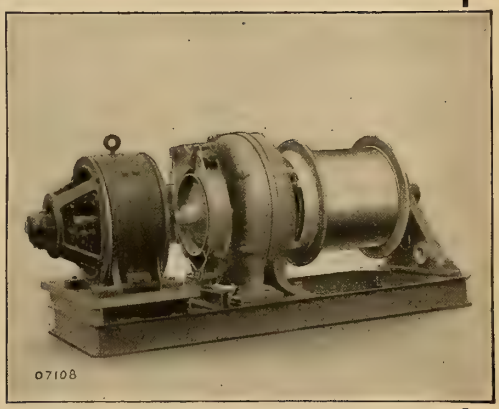
Hoisting machinery of to-day is built, by the best makers, with the same care and skill as the highest grade of machine tools, with cut gears, with interchangeable parts, and with the same care in the proportions of parts to resist stresses as is given to other modern structures. When machines of this class are equipped with modern electric motors the combination produces results which reach the maximum of efficiency and endurance—results which would have been considered unattainable under older conditions and with less complete appliances.

"HUNT" ELECTRIC HOIST

Direct Current, any voltage
Alternating Current, any frequency



Gear Electric Hoist



Electric Hoist, with Gearing Enclosed

Hoists for Loads of 1,000 or 1,500 or 2,000 pounds carried in Stock.

These hoists are simple and rugged in construction and every hoist we send out is guaranteed to do the work for which it sold.

The use of an electric hoist is economy, as power is used only when the hoist is in operation.

Ready for use at any time by leading the wires to a source of electric current, and is adapted for use with either direct or alternating current motors.

The gears have machine cut teeth and all parts are interchangeable.

Write for bulletin F. 4, and also tell us the work you wish to accomplish, and we will furnish the hoist that will do it.

C. W. HUNT COMPANY

(ESTABLISHED 1872)

Main Office and Works: WEST NEW BRIGHTON, N. Y.

New York Office: 45 Broadway

Standardization

MORE than a hundred years ago two great mechanical geniuses undertook to standardize the manufacture of what was then one of the most important elements in hoisting machinery. Maudslay, the most eminent machine constructor of his time, built for the Government Dockyards at Portsmouth, England, from the designs of the elder Brunel, a very complete set of machines for the manufacture of wooden tackle-blocks.

The outfit included forty-four separate machines of twenty-one different kinds for making, by repetitive processes, the parts for the tackle-blocks required for the rigging of British naval vessels of all kinds. Brunel had systematized the various sizes and styles of blocks required, and found that about 200 varieties were necessary, but that it was possible to design these so that many of the parts would become interchangeable, and that the standard designs might be manufactured, not only to far greater advantage than under the old arbitrary and empirical methods, but also with the result of producing an article of higher grade, in much greater quantity.

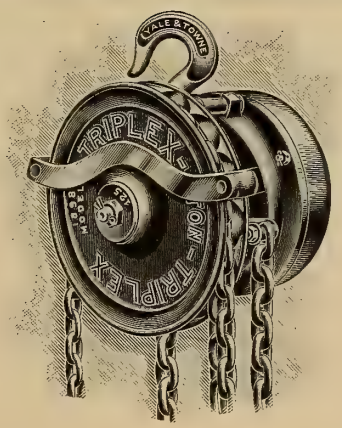
It is most interesting to note that this, one of the first examples of what may be called the modern method of standardization in manufacture, was applied to hoisting machinery. To-day standardization has been carried far beyond the ideas of Maudslay and Brunel in 1802, but the difference is one of degree rather than of kind. Eli Whitney had introduced the standard system into the manufacture of firearms in Connecticut as early as 1798, and his ideas led, in America, to a development of much the same sort as the work of Brunel in England.

It is always a matter for judgment and discretion as to the extent and nature of successful mechanical standardization. There is no doubt that mechanical repetitive processes enable work of the highest grade to be produced in the most efficient manner, and that perfect interchangeability is commercially attainable only by the accurate standardization of every part of the product. For articles which are handled in large quantities, which are sold all over the world, and in which repairs may best be made by the replacement of the damaged part by a new piece, a standard system of manufacture is essential.

In order, however, that a system of standardization may be successfully applied, it is most desirable, if not absolutely necessary, that the article shall have reached the standardizing stage, so to speak. This means that the product of manufacture must have passed through the ordeal of commercial production, that it must have stood the test of severe and protracted service, and that the weak points, the unavoidable original defects, and the possible opportunities for improvement all shall have been discovered.

If standardization is undertaken too soon it is often found that undesirable features, points which have been discovered in the vicissitudes of rough, practical service, have acquired such a firm hold upon the system of manufacture that improvement has become extremely difficult, if not impossible. The "paralyzing influence of standardization" is a saying which is true enough when it is applied to a half-baked product, to a thing which is far from being ready for this latest refinement in modern manufacturing science; but it has no application to a specialized apparatus which has been tested in the course of years of practical usage.

Modern standardization, as we have seen, had its beginning in America, in the State of Connecticut, and in England in the manufacture of hoisting appliances. To-day one of the striking examples of effective standardization is found in what is probably the most effective hoisting appliance manufactured, and it is made in the same State of Connecticut.



A Standardized Chain Block

THE TRIPLEX BLOCK OF today is the result of more than a generation of experience in the manufacture of Chain Blocks.

Its parts are standardized and interchangeable and can be ordered by number from us or from our trade customers who carry them in stock.

SEND for a copy of the new edition of our catalogue which has other things in it than the Triplex Block. It shows a full line of hoisting apparatus, 3 types of Chain Blocks, Electric Hoists, Trolleys, Overhead Rail, Cranes, Winches, Etc.

The Yale & Towne Mfg. Co.

9 Murray Street, New York

FOREIGN WAREHOUSES: The Fairbanks Co., London and Glasgow. Fenwick, Freres & Co., Paris, Brussels, Liege and Turin. Yale & Towne, Ltd., Hamburg. F. W. Horne, Yokohama.

Getting Around the Corners

IT is very probable that the first attempts to transmit power to any distance was by means of a rope. First as an appliance for hoisting, later to transmit power from one revolving wheel to another, or from a treadle to a spindle, as in the early foot lathe, and thence to other mechanical appliances, the rope appears to have been the predecessor of the belt, and to have been replaced by the latter only when the amount of power seemed to be too great for a single rope to transmit under conditions of speed and location then existing.

Hampered by the speed limitations of the time, the millwrights of the early factory system, following the precedents set by Fairbairn and his followers, the use of heavy, slow-running shafting and gearing acquired a reputation as the only way to deliver power through a mill from the engine to the machinery, and it was not until higher speeds of shafting came into general practice that belting replaced gearing in general use. The same development caused a revival in the use of rope transmission, and especially since the commercial production of grooved pulleys became possible, the employment of rope driving, either with the English system of independent ropes or with the American system of re-duplication of an endless single rope, became general.

The early methods of transmitting power in this way, by the use of what Professor Reuleaux has called "wrapping" connections, were limited to the delivery of power from one shaft to another parallel shaft. If any other relation of the position of the driving or driven shafts became necessary, various clumsy expedients were devised to hold and guide the belt. When the power had to be delivered around a corner, or transmitted from one shaft above or below to another at right angles in another plane, there appeared the necessity for using what has been termed the quarter-turn belt, a device which every mechanic dislikes, but which he formerly felt compelled to use under such conditions.

With the modern American system of rope driving, however, the whole question of the delivery of power from one point to another is released from any strict limitations as to the relative position of the shafts, while to a large extent the question of distance is eliminated.

Rope-driving connections have been designed for the transmission of large powers with distances between centres as close as 9 feet and as wide as 700 feet, while the question of angular position of the shafts is always capable of effective solution. Experience has shown that by the use of rope transmission the highest degree of efficiency is attained, the friction losses being kept at a minimum, while the maintenance expense is lower than with other forms of power transmission.

These results are not obtained, as it may well be understood, by the mere substitution of rope for belt driving; it is essential that the installation be designed carefully for the situation in which it is to be used. Only in the light of the teachings of long experience has the modern system or rope driving been evolved, and while it seems probable that the various difficulties in this department of work have all been encountered and overcome during the past twenty-five years, yet even in this respect it is possible that special and novel conditions may yet arise.

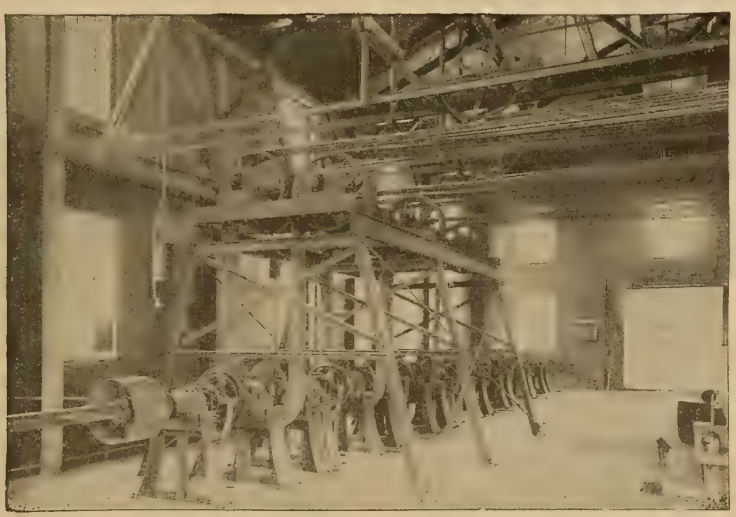
In any case, it is advisable that a rope transmission should be designed and installed by specialists in this particular department of power transmission, both on account of the necessity for application of experience and because the engineer who has already become familiar with existing installations may be able to suggest methods and applications which would not occur to the mechanic, however able, who lacked familiarity with the almost infinite variety of which the system is capable.

DODGE

Designed Rope Drives

are transmitting large powers between centers as distant as seven hundred feet; and between centers as short as nine feet; at all angles, indoors, outdoors. During the last twenty-five years we have designed and furnished rope drives which have successfully solved many other varied power-transmission problems.

Every one of these drives is operating with the best possible efficiency, with the least friction loss and the lowest cost of maintainance.



Our experience demonstrates that Dodge Designed Rope Drives would effect a great saving in transmission, if installed in many situations where other methods are now employed. If you are interested in the application of rope driving to the transmission of power, fill out the coupon below for a copy of our new book, C. 76, "Twenty-five Years of Rope Driving," which shows some of our achievements in this line. On receipt of necessary data, power to be transmitted, speed of driver and driven, distance between centers, etc., we will be glad to advise with you regarding the installation of a rope drive.

New York
St. Louis
Cincinnati
Philadelphia

Dodge Manufacturing Co.
Station L. 11, Mishawaka, Ind.

Chicago
Boston
Pittsburg
Brooklyn

Dodge Mfg. Co., Station L. 11, Mishawaka, Ind.

Send me Bulletin C. 76, "Twenty-Five Years of Rope Driving."

Name..... Firm .....

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Mechanical Adaptability

NOT long ago a practical man was attempting to install a pumping appliance and found that it failed to give acceptable service under conditions which seems entirely reasonable. A communication to the manufacturers elicited a response which stated very plainly that the apparatus under consideration was operative only under conditions very closely limited by dimensions, distances and relations for which the mechanism had been designed, and that all the surroundings would have to be altered before the machine could be expected to work.

The impression produced upon the owner, as well as upon several engineers to whom the correspondence was submitted, was that the machine was sadly lacking in adaptability, and that the exertion of a small amount of ingenuity on the part of the designer might have resulted in the production of a much more useful apparatus.

When a man is out in the field, or deep in the mine, or in the outlying shop, far from the establishment of the manufacturer, it gives him small satisfaction to know that, under conditions altogether different from those possible with him, the machine would operate all right. He has to get along with what he has, and the apparatus which is so highly specialized that it dominates all its surroundings will be found to have very limited usefulness in the long run.

It is true that certain special devices may be made of extremely high efficiency and precision when the exact conditions under which they are to be operated are given beforehand; but the maintenance of those operative conditions is not always practicable, and it may often be found far more desirable to have a little more adaptability and a little lower efficiency than otherwise.

It has been well said that the theoretical man takes into account all the conditions which can be ascertained, but that the practical man has to take into account all the conditions there are! If one could ascertain all the conditions to be met, there would be little or no difference between the theoretical and the practical man, or between the specialized and the adaptable machine. Since, however, it is not always possible to determine the conditions under which a machine is to be used, the wise engineer provides for reasonable limitations in usage and produces an apparatus of far greater real value than if he had limited himself more closely.

It is not uncommon to find machines designed with a high degree of ingenuity as regards some detail of operation or for the attainment of some remarkable efficiency in the utilization of power, while at the same time such a device may be so unreliable or so limited as to adaptability as to be altogether undesirable in practical service.

The most desirable plan for the designing engineer, whenever possible, is so to arrange his product as to permit of a fair degree of overload with a minimum loss in efficiency, while at the same time providing such a degree of flexibility as will allow the apparatus to be used within broad operative conditions. Reliability, adaptability and efficiency, in the order named, are the qualities which appeal to the highest degree to the practical man, and it matters little to him to know that the machine which stands idle before him would be all right somewhere else, when he has to contend with an emergency himself, and when, possibly, the success of an enterprise, or even the safety of human life, may be in the balance.

It has been said that common sense is the most uncommon thing in the world; and it may be said with equal truthfulness that the reliable, adaptable machine is the one most rarely met with and the most highly appreciated when it is found in time of emergency.

Manufacturing News

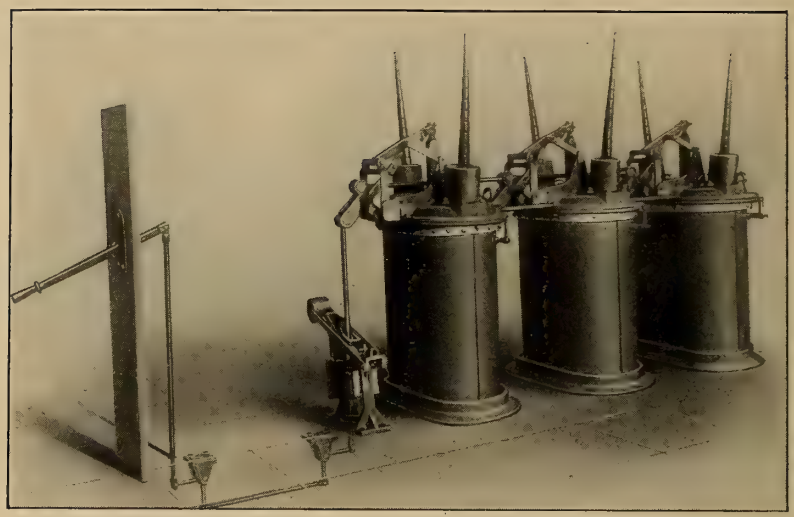
110,000-Volt Circuit Breakers

THE Southern Power Company has recently installed four 110,000-volt circuit breakers on its high-tension lines in the vicinity of Charlotte, N. C. This is the first instance of the installation of circuit breakers for so high a potential, although similar plants now being constructed will soon be in operation.

In the case of the above-named company, it is not only the voltage interrupted which calls for attention, but also the magnitude of the currents which are successfully handled under such severe conditions. The design of these high-tension control apparatus, which will successfully interrupt any short circuit occurring on a transmission system of 120,000 KW. capacity, marks a considerable progress in the manufacture of these apparatus.

The illustration shows the isolation of each pole in a separate tank, the pole thus being entirely independent of all others except for the pull rod operating the contact. The tripping mechanism at the left of the tanks releases the rods and allows the contacts to open by gravity. The 47-inch break thus interposed in each phase occurs in the center of the tank, in oil free from any possible sediment or moisture. By arrangement of the operating mechanism, gravity assists in making a quick break during normal operation, while in case of any injury to the circuit-breaker parts the circuits naturally tend to fall open. At each pole is a double-break, spring-seated butt-contact assuring firm closure. A small double-pole, double-throw switch operated by the contact mechanism indicates the position of the breaker contacts by lighting a red or green lamp. The tanks are of welded-seam boiler steel filled with oil and fitted with a thick lining of specially treated insulation which encloses the contacts. The terminals are of the condenser type, and allow the line wires to be brought in directly from overhead.

The 110,000-volt breakers for the Southern Power Company are of both the hand and electrically-operated types. They are normally closed by energizing the operating solenoid from a low-voltage local circuit, but may also be hand-operated by a lever handle through a simple mechanical connection. Series relays, mounted on suspension insulators and inserted directly in the line, are provided for automatically tripping the circuit breaker if overloaded. A wooden rod transmits the movement of the relay armature on the suspension insulator to the latch mechanism, pro-



HAND-OPERATED WESTINGHOUSE OIL CIRCUIT BREAKER

viding a simple and quick-acting mechanical release effected directly by the line current.

The 44,000-volt lines of the Southern Power Company, who will also install fifteen 88,000-volt circuit breakers, are controlled by five sets of breakers of form similar to the high-voltage apparatus already described, but designed for operation at the lower voltage. All these circuit breakers are of the "GA" design, developed and manufactured by the Westinghouse Electric & Manufacturing Company, Pittsburg, Pa.

The American Exposition at Berlin

THE importance of the All-American Exposition which will be held in the capital of Germany during the months of July and August, 1910, cannot be overestimated. It will be the first exhibition of its kind in a foreign country, and it will be a thoroughly qualitative exposition, which will enable the manufacturers and business men of Europe to form a clear conception of American industry and machines such as most Europeans do not have to-day. They will, through this enterprise, become fully aware of the progressiveness of American industry and business methods; they will comprehend, what has hardly been the case until now, the economic strength of this country, as shown in its rapid recovery following the recent depression; and they will come to believe in the integrity of American production and trade, and this increase of confidence will greatly help to steady business and national prosperity both here and on the other side.

To attain this end, the American committee, under the direction of the principal financial leaders of the United States, intends to show to the people of Europe what has been accomplished in America along every line of endeavour. While the space occupied by this exposition will be small in comparison to that of universal exhibitions to which we have become accustomed, it is understood that the success of this undertaking, which appeals mostly to European business men, will depend upon the intrinsic value of the products shown.

Therefore, the best of America's products should be exhibited, and as a lively interest in the exposition is being taken throughout the country and the committee has received applications for space from many States, it may well be assumed that every

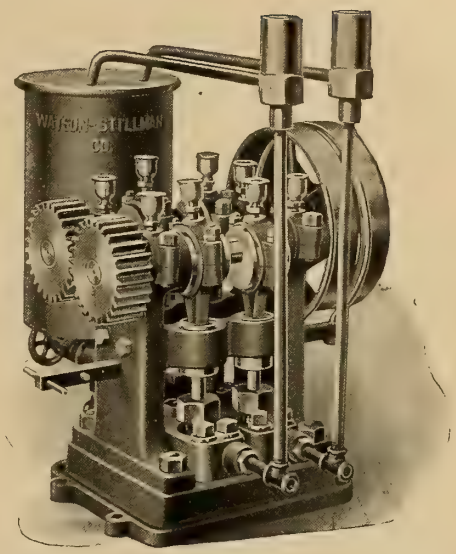
branch of American progress will be represented.

As regards the selection of the German metropolis for the place of this exposition, Berlin must be considered the most appropriate locality. American exports to Europe for the year 1908 amounted to $1,270,016,773, and of this Germany consumed about $274,178,712—i. e., 21.58 per cent. Berlin, the heart of the German Empire, is to-day one of the most important strategic centers of the world's commerce, and its life and traffic are in more than one respect similar to American conditions. During midsummer it is the goal of thousands of tourists of all nationalities, the rendezvous of many Americans, and, above all, the residence of the most intelligent and progressive population existing on the Continent. The Exposition Palace, one of the most modern structures, was erected in 1907 at a cost of one and one-half million dollars, and is easily reached from Berlin's business center, as well as from its principal residential quarters.

The success of this exposition is already assured. Excellent management, first-class display of standard goods and ample publicity will bring about the effect desired, namely, the broadening and strengthening of our foreign markets, the establishment of closer relations between America and Europe, and the advancement of America in the international economic race.

A Small but Powerful Hydraulic Pump

THE four-cylinder, two-pressure-line hydraulic pump illustrated represents a new Watson-Stillman type, by means of which one, two, three or four pressure lines may be served independently of each other, but from a common reservoir. Each pressure line has a separate pressure chamber, safety valve and release line, and is served by a separate pair of cylinders (½ inch diameter by ½ inch stroke)



FOUR-CYLINDER, TWO-PRESSURE LINE HYDRAULIC PUMP

having eccentrics set to give a continuous flow. Any pressure up to 600 pounds per square inch may be delivered into any line, the limit in each instance being determined by the setting of the safety valve, which opens as the pressure tends to exceed the limit and lets the surplus liquid pass back through the release pipe to the reservoir. Any pressure line can be thrown out of service entirely by opening the safety valve, in which instance all the liquid in that line pumps directly back to the reservoir.

The one, two, three and four pressure line pumps are practically the same in design save for change in the length of the bed plate and the shafts to accommodate the required number of pressure chambers, cylinders, piston rods, eccentrics, etc., and may be fitted with an electric motor instead of the pulley shaft shown. These pumps are made by the Watson-Stillman Company, of New York.

News Items

The contract for placing concrete piles and foundations for the United States Post Office that is to be erected at Manistee, Mich., has been

awarded to the Raymond Concrete Pile Company, of New York and Chicago; James Knox Taylor, supervising architect, United States Treasury Department; Majestic Construction Company, general contractors.

The British Corporation for the Survey and Registry of Shipping at Glasgow, after exhaustive tests, has sanctioned the use of the thermit process for repairs to fractured sternposts, lower portions of rudder frames and damages of a similar character.

The Bigelow-Harriman Construction Company has placed with the Raymond Concrete Pile Company, of New York and Chicago, the contract for the concrete piling of a paper mill which is building at Montville, Conn. Geo. F. Hardy is the engineer.

The city of Thomasville, Ga., has recently placed with Allis-Chalmers Company an order for the following electrical machinery, to be installed at the municipal lighting plant: One 250-KW., 2,300-volt, 600-r.p.m., three-phase, 60-cycle, three-bearing-belted generator; one 15-KW., 116/120-volt, 1,150-r.p.m. exciter of the same type. Allis-Chalmers Company, who installed one of its 1,500-KW. transformers at the plant of the Delaware, Lackawanna & Western Railroad a year ago, have now been awarded by the same concern a contract for the installation of two 500-KW., 6,600-2,300-volt, three-phase, 60-cycle, water-cooled transformers at Kingsland, N. J.

The main machine-shop addition at the plant of the Dodge Manufacturing Company being completed, this concern has had ground broken for another warehouse for finished products. The reason for this enterprise is two-fold, viz., the present warehouse being inadequate to take care of the full volume of business, and the endeavour of the firm to continually improve the service.

The structure, of reinforced concrete, will be 256 feet long, 112 feet wide, will have a basement and four stories, and is estimated to cost about $160,000.

On the first floor, which is raised to a level with the floor of a freight car, will be situated the offices of the general traffic manager and his force, and this floor will be used mainly for shipping and inspecting purposes. The basement and the other floors will be confined to the storage of products. The warehouse will have elevator facilities, and will be equipped in the most modern manner.

A loading platform, with ample trackage for loading and moving cars, will extend the entire length of the warehouse. The Lake Shore & Michigan Southern Railroad, which has already extensive yards at the Mishawaka factory, will be directly connected with the warehouse. The standard equipment will make possible as fast a filling of orders for the standard goods of the company—pulleys, pillow blocks, hangers, collars, couplings, clutches and other machinery—as the railroad company can furnish cars for the loading and taking away of the products.

Advanced Instruction in Electrical Engineering at the Massachusetts Institute of Technology

THE requirements by this institute for the degrees of Doctor of Engineering and Doctor of Philosophy have now been made substantially equivalent, as far as the period of study and the candidate's attainments are concerned. The executive committee has voted to maintain the graduate scholarships and fellowships, which numbered seventeen this year.

During the present year seventeen candidates for advanced degrees have been awarded fellowships or graduate scholarships. Two of these were for the encouragement of advanced study in Germany by graduates of the Institute of Technology and the remainder for the encouragement of

advanced study in the Massachusetts Institute of Technology.

The number of candidates for the doctor's degrees in engineering and philosophy, as well as the number of students entered as candidates for the master's degree, have considerably increased over last year's corresponding figures.

Dr. Harold Pender will continue as professor in the electrical engineering department this year, lecturing on the theory of alternating currents and electrical transmission of power. His duties include also the direction of the undergraduate course of elementary electrical engineering for the junior students and naval instructors. Students desiring to do original research work or to obtain advanced degrees are benefited by the lectures and investigations under Professor Jackson on the organization and administration of public service corporations, while the instruction in the designing of electric plants rests in Professor Wickenden's hands.

The undergraduate classes grow even more rapidly than those for advanced study; especially is this the case with junior and senior classes constituted by the graduates of various humanistic or scientific courses. The increasing number of students following the electrical engineering instruction is particularly felt in the laboratories, and the number of student hours of instruction in the electrical engineering laboratory is now twice as great as it was three years ago.

A New Safety Cutter Head

A NEW cutter head for hand planers and jointers, which assures maximum safety to the operator by reason of its permitting the tables to be set very close together, has lately been introduced in the woodworking machine tools manufactured by the J. A. Fay & Egan Company, 226-246 West Front street, Cincinnati, Ohio. In the old-style cutter head, with the square blocks and knives bolted to its sides, the square shape of the block would neither permit the tables to be set close together nor did the head itself fill the opening between the tables. Thus, with the slightest slip on the part of the operator his fingers might be drawn in between the tables and badly mutilated, if not lost.

NEW SAFETY CUTTING HEAD. THE J. A. FAY & EGAN CO.

The new safety circular cutter head closely fills the opening between the tables, so that the most severe accident that could possibly happen would be the scraping of a finger or thumb. The new head is made from a solid piece of crucible steel, which is first roughed on a lathe to the desired circumference and then ground accurately to size. Afterwards seats for the two knives are milled into the steel body. High-duty tungsten-steel knives are used on this cutter head and are held in the milled slots by special blocking, which is wedged against them by sets of cup-head clamp screws. The design is such that the cutting edges of the knives protrude but slightly from the cylindrical-shaped head, and thus permit the tables to be set very close to the cutter.

You are requested to write the manufacturers for their new Catalogue No. 81, which describes and illustrates their new safety circular cutter head in full.

Asphalt Lumber

THE term "lumber" formerly was applied only to wood; but it has now been combined with the word "asphalt" to form a term so new as to be capable of copyright, and to mean a board-like product which, while composed of layers of a special long-fibre felt saturated with a composition of asphalt, can be cut, worked, joined and nailed like wood.

This material, originally designed for roofing, and absolutely water and weather-proof, is manufactured in a stock size, 36 inches wide and 6, 8, 10 or 12 feet long. The boards are made with a 1-inch rabbet, running the full length on either side, enabling the material to be matched up readily and quickly, while a special asphaltic cement applied along the rabbeted joint makes the joints practically a part of the solid board.

Such a material naturally has many wider applications than those merely of roofing construction, and it is available in all building operations demanding a waterproof structure, capable of resisting heat or cold, and unaffected by the action of acids, gases, fumes, etc. The material is compressed in the course of manufacture to such a solid consistence that it may be classed as a fire retardent, while it may be surfaced with sand, gravel or mastic, as may be ordered.

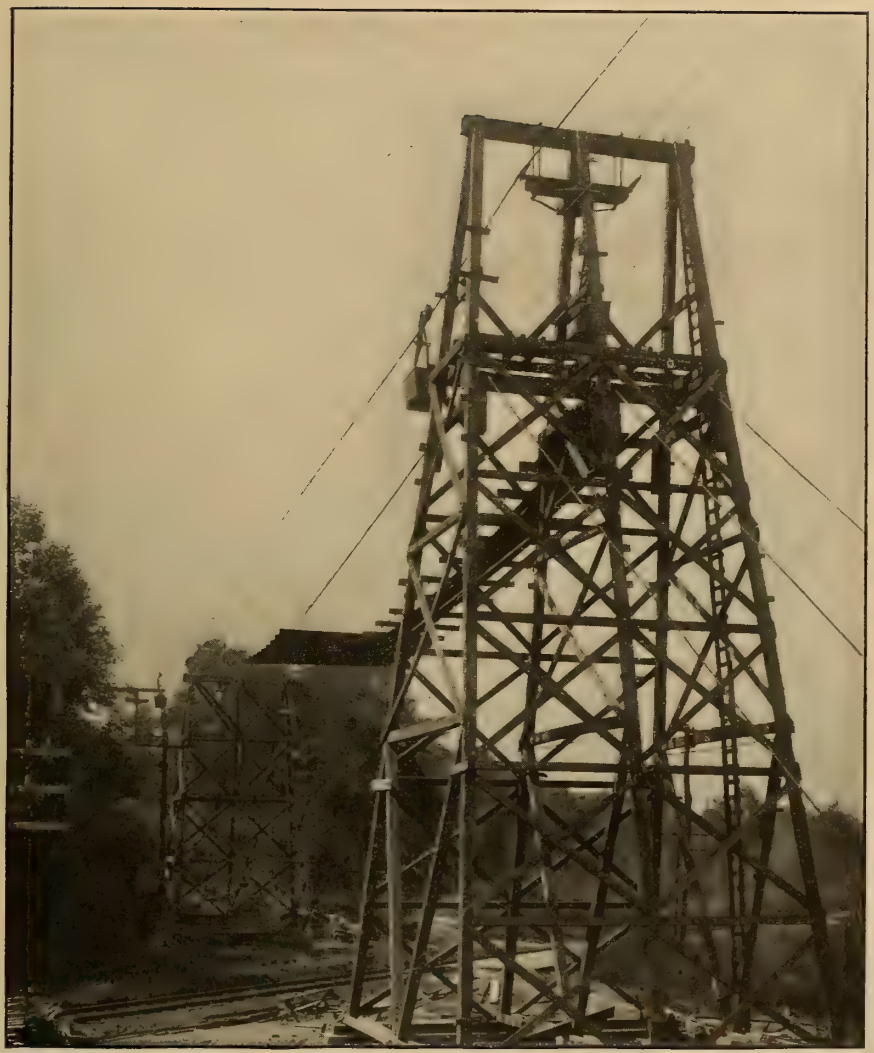
In the manufacture of Asphalt Board there are used four layers of saturated felt, three of parchmentized cellulose, and six of cementing composition, to which are added two weather coats applied to the outside. Important details in the manufacture include the maintenance of correct temperatures and the application of heavy pressure, all the various operations being performed by machinery.

Further information about this valuable and interesting material may be obtained from the Consolidated Waterproof Company, 17 Battery place, New York, N. Y.

An Important Rope Tramway Installation

THE use of aerial wire rope tramways for the transportation of material from one point to another constitutes one of the most economical methods on the market today. Heretofore aerial wire rope tramways have been confined, with few exceptions, to the transportation of ores in the mountainous sections where railroads are too costly to build, owing to winding detours, bridges and cuts, and also where the elements operate against railroad construction. Their field is not, however, limited to the mining industry, as aerial wire rope tramways can be just as economically used in industrial plants, cement propositions, lumbering districts, etc.

Up to quite a recent date aerial wire rope tramways were built to



VIEW ALONG CABLEWAY LINE OF THE CRESCENT PORTLAND CEMENT COMPANY, WAMPUM, PA., SHOWING TOWER AND PROTECTING BRIDGE. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

carry material up to a maximum of about 50 to 75 tons per hour. The modern requirements, however, have made it necessary to go beyond these limits in order to cope with the ever-increasing output of the factories and mines.

The A. Leschen & Sons Rope Company have specialized heavy-duty tramways, with the result that they are to-day able to equip aerial wire rope tramways with a capacity of transporting as much as 200 tons of material per hour when required. This result was accomplished by extensive experience and exhaustive trials by not only strengthening component parts of the cables and equipment, but developing new designs in all of the parts as required for the new conditions.

A recent installation of these heavy-duty tramways is that furnished by the A. Leschen & Sons Rope Company to the Crescent Portland Cement Company, Wampum, Pa., which

will be seen in the accompanying illustrations. This tramway is used for carrying cement rock from the quarries of the cement plant, a distance of approximately 3,100 feet. It is capable of transporting a continuous quantity of cement rock at the rate of 120 tons per hour, or 1,200 tons per day of ten hours.

The type of tramway is known as the Leschen Company's heavy-duty, friction-grip type, having carriers which are automatically detached at each terminal station and mechanically attached. The carriers hold a bucket that contains one ton of cement rock, and travels at the rate of 450 feet per minute. The carriers are of a very heavy design and fitted with the screw type of friction grip, arranged with a quick-acting jaw on one side and a slow-acting jaw on the other to grip and encircle the rope. The advantage of this is that when a bucket is being gripped or ungripped the rope has no opportunity to run through the jaws and produce wear. The principal advantage, however, in the construction of the grip used is that, owing to its

DEVICE FOR ATTACHING THE BUCKETS TO THE CABLE AT THE TERMINALS. A. LESCHEN & SONS ROPE COMPANY, ST. LOUIS, MO.

screw type, it allows for variations in the diameter of the traction or pulling rope without adjustment. This simple arrangement means a great deal to the operator, because it insures the safe transit of the buckets from one terminal to the other without any fear of disengaging or slipping.

The sheave wheels of the carriers are of cast steel, and have an improved type of oil cup for lubricating the journals. Practically all castings on the bucket are made from cast steel, to insure strength and economy.

The track rope on which the loaded buckets travel is 1¾ inches diameter, while the cable on which the empty buckets travel is 1 inch diameter, both of the patent locked coil construction of rope, manufactured by the A. Leschen & Sons Rope Company for these heavy-duty plants.

The traction or pulling rope to which the buckets are gripped and ungripped is ¾ inch diameter and of the patent flattened strand construction, also made by A. Leschen & Sons Rope Company.

The ropes are supported in the present installation by ten intermediate supporting towers.

The track ropes rest in saddles which are mounted on a shaft, thereby permitting the saddle to dip with the variation in the inclination of the cables. This is a rope-saving feature of considerable merit.

One of the illustrations shows a carrier in the act of attaching to the traction or pulling rope. All that is done is that when the spacing gong rings the operator moves the bucket to the attaching point and lets it go. The bucket runs down a small incline, and, in doing so, the lever controlling the grip is thrown over, allowing the bucket to become attached to the cable and travel to the opposite terminal.

The cement rock is not loaded from a bin into the tramway carriers. By means of an air hoist at the terminal, in conjunction with a movable section of the terminal rail, two carriers at a time are lowered and place the buckets in these two carriers on a surface car. These cars are then run to the quarry, and after they are loaded they are then returned to the line and engaged to the tramway carriers.

The tramway has a fall of 88 feet from loading to discharge terminal, which means that power is necessary. This power is applied at the discharge end from a bevel gear with pinion and friction-clutch pulley.

The A. Leschen & Sons Rope Company supply tramways for less duty, and are in position to furnish automatic styles of equipment where exceedingly low labor cost is obtained, and, at the same time, the cost of maintenance is kept down to a low limit.

The A. Leschen & Sons Rope Company have their headquarters at 920-932 North First street, St. Louis, Mo., and have branch houses at the following points:

New York, N. Y.—West Street Building, 90 West street.

Chicago, Ill.—137 East Lake street.

Denver, Col.—1649 Wazee street.

Seattle, Wash.—313 Pacific Block.

Anyone desiring estimates or information for any tramway proposition will do well to communicate with this firm.

Every one who has observed the "chugging" of the automobile motor or the engine of the noisy motor boat will welcome the idea that it may soon be possible to have a gasoline motor which, while running at thousands of revolutions per minute, will be silent, smooth, and powerful in action. The possibilities of such a motor lie in the development of the gas turbine, and in a new book, the first yet written upon this subject, Mr. Henry Harrison Suplee has gathered such information as is now available. This book, entitled "The Gas Turbine," has just been announced by Messrs. J. B. Lippincott Company, of Philadelphia.

THE LATEST CATALOGUES

In writing for Catalogues, please mention Cassier's Magazine

Oil Engine

American Diesel Engine Company, St. Louis, Mo. Booklet containing detailed information about the Diesel engine, its various types, its design, construction, operation and characteristics. Plants and Diesel installations are shown, and a number of tables relating to the efficiency, consumption, etc., of Diesel engines added.

Tubs and Buckets

C. W. Hunt Company, New York. Catalogue of steel tubs for dumping coal and excavating work; also, of the "Duplex" and "King" grab buckets. There are also illustrations of special tubs, of various elevating machinery, electric hoists, cableways, chain-blocks, etc.

Hydraulic Machinery

Waterbury-Farrel Foundry & Machinery Company, Waterbury, Conn. Catalogue H contains hydraulic machines as are used in various industrial operations: embossing, automatic and vertical drawing presses; horizontal push, pull and draw benches; hydraulic accumulators and such mounted together with pumps, power pumps, hydraulic forcing machines, throttle, stop, reversing and pressure stop valves, etc. The company is prepared to build new machines for special purposes, and also to construct piping and valves suitable for connecting its pumps and accumulators with the machines they operate.

Storage Batteries

Electric Storage Battery Company, Philadelphia, Pa. Bulletins Nos. 116 and 117 contain descriptions of storage batteries for vehicles, for signal and car-lighting service; installation, care and operation of the batteries are described and illustrated with many interesting details.

Water-Power Machinery

Pelton Water Wheel Company, San Francisco, Cal. Catalogue giving detailed account of theory and practice of the Pelton water-wheel and the Pelton-Francis turbine, which latter is intended especially for low-head streams of water. Pelton motors of 6 to 24 inches diameter and standard wheels of 3, 4 and more feet diameter are described and illustrated, as are various plants and their ways of connection to electric generators. Valves and pipes are shown; tables give capacity and speed of wheels and prices of same. Pelton wheels mounted to air-compressing and pumping plants, list of installations of Pelton apparatus and data of such are added.

Superheaters

Power Specialty Company, New York. Catalogue describing the Foster superheater built by this firm. The machine and all its parts are dealt with and production and properties of superheated steam treated. The catalogue contains also descriptions of the Willits combination steam valve, an automatic stop valve for superheated as well as saturated steam, the Harter flexible joint and the Duval metallic packing.

Electric Motors

Northern Electrical Manufacturing Company, Madison, Wis. Bulletin No. 50A describes and illustrates various types of spherical frames, some of which are used both as dynamos and motors, while some have been applied in the construction of back-geared motors, universal and vertical motors, emery grinders, buffing lathes, etc. The tables included in this booklet will prove of value to users of electrical power and to electrical engineers.

MANUFACTURING NEWS

Valves

Golden-Anderson Valve Specialty Co., Pittsburg, Pa. Catalogue No. 12 covers the different types of the Golden cushion, triple-acting, non-return valves, which combine the properties of automatic non-return valves, automatic safety stop valves, automatic emergency stop valves and hand stop valves, and can be looked upon as warranting the safety of the boiler or power plant where they are applied.

Panel Boards

General Electric Company, New York. Bulletins Nos. 4,692 and 4,693 of this company are devoted to the description of two of this firm's railway motors, which are treated in detail. The publications contain all data regarding the machines and their parts, tables of schedule speeds and various characteristic curves and motor dimensions.

Electric Lamps

Sterling Electric Manufacturing Company, Warren, Ohio. Bulletin No. 8A deals with tungsten miniature and low-voltage lamps (1.5 to 20 volts), intended for batteries, signs and automobiles; also, with large, low-voltage lamps of 20 and 24 candle-power capacity. Bulletin No. 7 contains several interesting tables of data on illumination, which are compiled especially for the use of architects, mechanical, building and illuminating engineers, college professors and students and electrical engineers.

Circuit Breakers

Cutter Company, Philadelphia, Pa. Describes and illustrates circuit breakers of every type on the market; also, switchboards for power and manufacturing plants, etc. The apparatus shown in this book represents a complete line of these machines.

Water Filtration

James Beggs & Co., New York. Catalogue No. 35 treats of the Blackburn-Smith feed-water filter and grease extractor, and illustrates its application for the purification of boiler water from mechanical impurities suspended in the water, such as organic matter, sediment, lubricating oils, etc., by many pictures taken from installations of this filtering system. The operation of the filter is described in detail; the booklet is of interest to all connected with boiler and soft-water work.

Plowing Machinery

M. Rumely Company, La Porte, Ind. The booklet, "Toiling and Tilling the Soil," which is published by this company, deals with the description of the plowing-engine "Oil-Pull" and its superiority over the plowing application of animal power. The machine and its parts are described, its effect shown and the results of its application given in tables of fuel consumption and efficiency.

Forgings

Cleveland City Iron & Forge Company, Cleveland, Ohio. This catalogue contains general and specific information about the numerous products of this company, among which are bolts and their parts, car forgings, jaws, nuts, pins, round bars, stubs, turn-buckles, etc. The booklet contains also many tables covering subjects of interest to most engineers.

Shop Furniture

New Britain Machine Company, New Britain, Conn. Catalogue treating of machine-shop appliances, such as tool racks, lathe racks, lathe pans, steel racks, waste cans, shelving, etc. Code-words and prices of every product are given. The above-named company also makes a chain saw mortiser, of which several types are constructed, for heavy and light, fine and quick work.

Power-Station Auxiliaries

ALTHOUGH the prime movers in power stations naturally hold the most important position, there are necessarily a number of auxiliaries, and it is upon the convenience and design of these auxiliaries that much of the efficiency of the station depends. Leaving aside for the present such machinery as is connected with the water supply and with the general handling of material, we may consider the apparatus which is required in the handling of the fuel. Nearly every large power station in which steam power is employed is now situated near some stream or body of water upon which the coal can be brought in barges. If such a situation is impracticable, it must have railroad connections for the transport of its fuel supply; and, in any case, there must be a powerful and reliable equipment for the prompt handling of the incoming fuel and for the removal of the ashes.

Coal-handling machinery for power-house service has been brought to a high degree of perfection, especially when the crude character of most of the early outfits is considered. The coal itself is a material which, from its very nature, is destructive and injurious to the working parts of well-fitted mechanism, unless the essential parts are thoroughly protected; and every one who has had to do with coal knows how penetrating such a substance as coal dust can be. If coal is difficult, it may be realized that ashes can be even more troublesome, and certainly fully as injurious to the machinery. It is also difficult to secure the services of skilled engineers to operate machinery under such disagreeable conditions, and hence it was formerly thought that the machinery for coal-handling equipment should be rough and crude, and that the principal requirement was that it should not break down under the strenuous surroundings.

With the general improvement in all kinds of mechanical appliances, however, it has been realized that the mechanism of the coal-handling portion of the plant should be brought up to the high standard of the rest of the equipment. The result was the design of steam-driven hoists of a character as high as that of the other auxiliary machinery, including the provision of gear-cases and protecting devices for the working parts. With these improvements came a general advance in the character of the entire design, so that coal-handling machinery began to assume an efficiency comparable with the principal machinery of the plant.

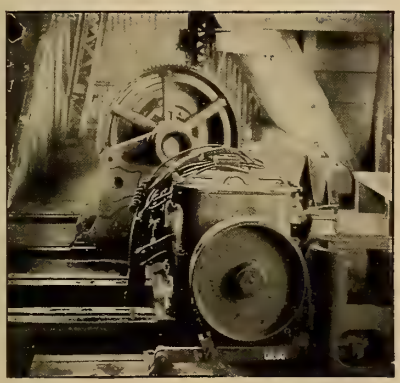
Since nearly all large power stations are occupied with the generation of electricity, it has often been suggested that electrically-driven auxiliaries might well be used wherever practicable. The use of electric hoists has now been found successful for elevating the coal from barges or cars to the towers and bins, and for operating the shovels and grab buckets.

It may well be imagined that the design of electric hoists, to be operated under the conditions accompanying the handling of coal and the removal of ashes, demands still more care than the construction of steam machinery. These requirements have been successfully met, however, and electrically-driven hoists, using cut gearing and provided with adequate controlling mechanism, are now widely employed for this difficult work. With either direct or alternating current, and possessing all the advantages of ease of power transmission and control from a distance, the electric hoist is displacing the steam-driven windlass in many power stations—another example of the general advance which is being made in apparatus for work which formerly was considered too rough for anything but the most primitive appliances.

Electricity is thus shown to be useful in its true function as a means for the transmission of power, regardless of the difficult nature of the work.

"HUNT" ELECTRIC HOIST

Direct Current, any voltage
Alternating Current, any frequency



No. 0250
Motor and Hoisting Drum Operating the Trolley on the Boom of the Steeple Tower. Load on the Rope, 6,000 Pounds

No. 0252
Motor Connected to Hoisting Mechanism Operating the Duplex Shovel of Steeple Tower. Height of the hoist 151 feet.

ELECTRIC HOIST EQUIPMENT IN A POWER STATION.

These hoists are simple and rugged in construction, and every hoist we send out is guaranteed to do the work for which it sold.

They are fitted with gear cases that enables them to stand any test of exposure to weather, dust or ashes, etc.

The gears have machine cut teeth and all parts are interchangeable.

Write for Bulletin F. 4, and also tell us the work you wish to accomplish, and we will furnish the hoist that will do it.

C. W. HUNT COMPANY

(ESTABLISHED 1872)

Main Office and Works: WEST NEW BRIGHTON, N. Y.

New York Office: 45 Broadway

Long-Distance Power

THERE has been more or less controversy among scientific men as to the possibility of such a thing as "action at a distance"; but there is no question as to the practical reality of such a thing, at least as it is viewed by the modern workman. It is not so long ago that he did consider that there must be some very visible and positive mechanical communication between the power developed in the engine room and the work performed under his eyes in some distant part of the shop, and he was very familiar with the troubles growing out of the use of shafting, belting and similar obvious methods of transmission.

There has grown up, however, of late years that marvelous thing which we call electric transmission—an example of the manner in which we become familiar with things to which we give names and manage to control without understanding in the least what they really are. The scientist confesses his ignorance of the real nature of the electric current; but the operator simply accepts it under the homely name of "the juice," and finds it extremely convenient in an immense variety of ways.

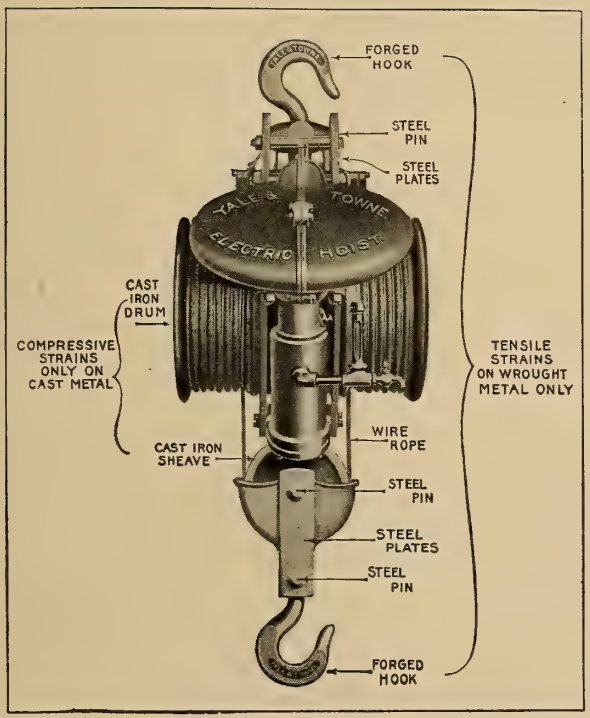
Those who remember the unwieldy and inefficient methods of getting power from the boiler and engine room to the work under the old conditions of affairs are, perhaps, best fitted to appreciate what immense progress has been made since the introduction of electric power. Many large works, such as rolling mills, shipbuilding yards, and the like, were threaded with hissing steam pipes, carrying energy in a most wasteful manner to small independent steam engines, themselves of very low efficiency, and connected by equally inefficient methods to machines operated at great disadvantages. In other cases there were several separate engine rooms, these being so placed as to permit the power to be transmitted by shafting, belting and gearing. In any case, there were large mechanical losses incurred in getting the power to the work, and still greater losses due to the inconveniences in its application and in the maintenance of satisfactory operation.

With the advent of electric power it has been found entirely practicable to have an entire establishment wired in such a manner as to have current available at almost any part of the establishment. The result has been the production of a large variety of electrically-operated machines suitable for immediate attachment and capable of most efficient and convenient use.

Among such devices the electric hoist has taken a definite position as a most useful application of long-distance power in the handling of materials. The mechanical hoist itself is capable of widely extended usefulness; but there is a large intermediate service demanding greater power and speed than can be secured by any apparatus depending wholly upon manual effort, and yet hardly requiring the installation of large power cranes. This gap has been filled in a most effective manner by the production of the electric hoist, a machine which is efficient in itself, and which, by the aid of the electric current, can be put in touch, so to speak, with the power house, however near or remote it may have to be placed.

It is well understood that the principal effort in handling materials is exerted in the operation of lifting, in overcoming the force of gravity, and that mechanical power is not so frequently required for horizontal transport of the load. It is thus easy to design simple forms of traveling cranes adapted to any locality, using the electric hoist for the lifting portion, and applying hand power for bridge and trolley travel, and thus accomplish all kinds of handling with a high degree of efficiency and with moderate initial cost.

The Era of the Electric Hoist



THE Electric Hoist is gaining favor rapidly and there can be no doubt that Electricity will shortly supplant all other forms of hoisting power. ¶ The flexibility of transmission, compactness, ease of control and dependability of Yale & Towne Electric Hoists as they are made today leaves no room for doubt as to their becoming the much used hoist of to-morrow. ¶ Many improvements have been made over former models in Yale and Towne Electric Hoists. ¶ The power of the motor is three times as great as formerly. ¶ Every provision has been made for the strain and stress of shop use, with the result that these hoists are at work all over the world, and are convincing their users of the advantages they possess over hoists operated by other power.

¶ *Let us send you our catalog which shows the practical applications of Yale & Towne Electric Hoists. A postal brings it.*

The Book of Hoists tells everything.
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Machine Design

THE art of designing machinery is one to which much attention has been given, but in which there is such a wide variety of subjects that its scope is often misunderstood. Many people think it is limited almost entirely to the design of machinery in the sense of machine tools, while others have in mind such prime movers as the steam engine, the hydraulic turbine, or the gas engine. Products such as the sewing machine, the typewriter, the modern rifle, and the like, must be accurately made, and hence demand the effort of the skilled designer and draftsman for the origination and delineation of every part, otherwise it would be impracticable to manufacture them in quantity with the degree of perfection demanded. It is with such work that the idea of machine design is popularly associated, and it is along such lines that many of the treatises and text-books occupy themselves.

The engineer, however, knows that the scope of the subject of machine design is far wider, and that many things which formerly were left to be worked out crudely by the ordinary mechanic are now given the close attention of the specialist, and form subjects for the designing engineer as fully as do the intricacies of a time-lock or the proportions of the parts of a steam engine.

Among these broad elements of machine design the department of power transmission is definitely included, not only in connection with the close limits of toothed gearing or the direct use of shafting, but also with the more flexible elements known as "wrapping connectors," these including belting and the various types of rope transmission.

The important part which the transmission of power plays in effective machine-shop operation is even yet not fully realized. The generation of power, including the design and proportions of steam boilers, steam engines, steam turbines, hydraulic turbines, gas engines, and similar prime movers, has occupied the attention of the ablest engineers for several generations, and the efficiency of the appliances, by means of which the latent energy of heat is converted into mechanical work, has been increased greatly by such efforts. In like manner the inventor has continually produced machine tools for performing every kind of mechanical operation with an ingenuity and effectiveness which attract the admiration of all mankind.

Between these two elements, the prime mover and the tool, there must come the transmission, getting the power, in the production of which so much care has been given, to the machine by which it is to be utilized. If this part of the whole is not considered as carefully and as skillfully as the extremes which are connected by it, the efficiency of all must suffer.

When the transmission is inadequate it is impossible to secure the maximum output from the machinery to which it must deliver the power. One of the significant results of the introduction of modern rapid-cutting steels appears in the general overhauling of the transmission which usually follows, the lack of symmetrical proportioning appearing in the difficulties which develop when the heavy cuts and feeds are demanded from tools which cannot have the proper amount of power delivered to them. With a properly designed transmission system every machine can be driven to its utmost and efficiencies attained which would otherwise be found impracticable.

Another feature about a well-designed transmission is found in the reduction in maintenance charges, and thus all along the line may be discovered evidences of the skill, or lack of skill, with which this element in a mechanical equipment has been handled.

The true way to secure the highest results in the transmission of power is to profit by the experience of others, and to place such work in the hands of competent specialists.

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Designed Rope Drives

are transmitting large powers between centers as distant as seven hundred feet; and between centers as short as nine feet; at all angles, indoors, outdoors. During the last twenty-five years we have designed and furnished rope drives which have successfully solved many other varied power-transmission problems.

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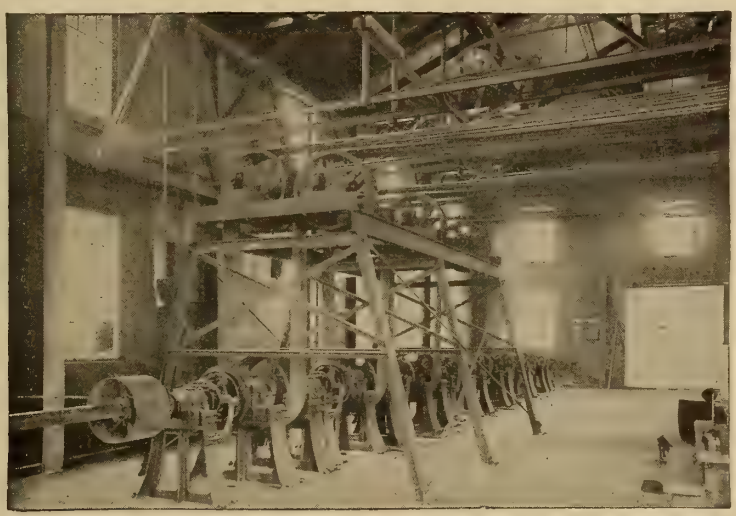

Our experience demonstrates that Dodge Designed Rope Drives would effect a great saving in transmission, if installed in many situations where other methods are now employed. If you are interested in the application of rope driving to the transmission of power, fill out the coupon below for a copy of our new book, C. 76, "Twenty-five Years of Rope Driving," which shows some of our achievements in this line. On receipt of necessary data, power to be transmitted, speed of driver and driven, distance between centers, etc., we will be glad to advise with you regarding the installation of a rope drive.

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Machine Shop Arrangement

THERE are various elements which have to be considered in designing the arrangement of machine tools in a shop. Formerly there was little or no system observed, the tools being placed where there was convenient space, and the operative difficulties being settled as they arose. The one thing which had to be considered was the getting of the power to the tool, and the placing of countershafts with relation to the position of the line shaft and with respect to the existence of places upon which necessary driving pulleys might be put demanded such positive attention that other considerations were usually ignored. Sometimes a new shop was laid out in such a manner that the operations to be performed followed in some kind of orderly sequence, and the power transmission was designed afterwards to correspond as nearly as could be contrived to permit the tools to be placed in the desired position. More frequently the machinery had to follow the transmission, and much of the waste of space and ineffective operation was due to the lack of flexibility thus occasioned.

The extent to which the rigidity of the power transmission affected the machinery is seen in the well-known fact that certain machine tools were designed in such a manner as to bring the driving pulleys in such position that the former necessity for placing the machine across the shop was eliminated, this being notably the case with planing machines and similar tools. The idea of reforming the transmission to suit the operative requirements did not really begin to gain ground until the advent of the electric motor, and the possibilities of independent driving gave an unwonted freedom to the works manager and designer.

When electric driving was first introduced it was, somehow, assumed that the only advantage to be gained from its use was a reduction in power-transmission losses, and various comparisons between relative economy of the newer and older methods were made. It gradually became apparent, however, that while the actual amount of energy required to get the power to the work might not differ very materially, the gains due to the use of the independent electric motor were very great in other directions. Thus, in a certain well-known establishment it appeared that a saving of nearly 60 per cent. in floor space could be realized by the rearrangement of the machinery as soon as the relation to any fixed position of overhead shafting disappeared. In various places the advantages secured in the placing of tools rendered proposed extensions of the buildings unnecessary, while in others the reduction in handling of material, due to greater convenience, permitted important reductions in manufacturing costs to be made.

Apart from such advantages, the use of the independent electric motor for the operation of machine tools gives, in large measure, freedom from vexatious delays due to interruptions of service. Of course, it is impossible to insure complete immunity from breakdowns in the main power plant; but it is not the least of the advantages of the electric system that the several machines are not dependent upon a whole system of transmission for their operation, but that each tool has its own connection to the source of power.

It is thus evident that the whole gain due to the substitution of electric driving for the older methods cannot be secured unless all the various lines of advantage are followed out, and in most instances this means that the benefit of past experience should be taken by the manufacturer, an experience which is already in the hands of builders both of electric machinery and of modern machine tools, as well as of those engineers who have devoted themselves to this important department of practice.

Manufacturing News

Steam Pile Driving

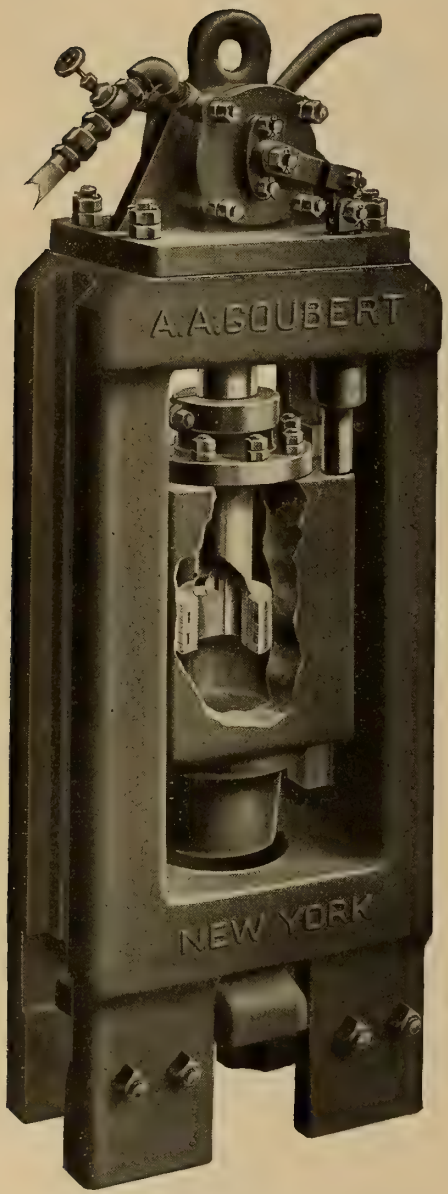
THAT the force applied must be greater than the resistance, is a primary principle in driving any pile, no matter of what make or size. If, for instance, a 3,000-pound weight is placed on top of a pile, the pile goes down until the resistance equals 3,000 pounds and then stops.

If the force is applied as a blow, there is a lateral vibration of the pile and a corresponding lateral compression or flow of the soil which lessens the resistance, but absorbs part of the driving force in doing so. This vibratory effect is greater at the top of the pile, becoming less and less as the pile proceeds downward. If the blows are far apart, the soil settles back against the pile, and the work expended laterally in freeing it is lost; but if the blows are repeated at very frequent intervals, the soil is kept "alive" and the work of driving is much easier.

The force of the driving blow is the product of the weight and the velocity at the instant of striking, but a heavy weight and a short fall is more effective than a light weight and a high fall. A light blow affects only the top of the pile, while the heavier the blow the further downward it is felt.

In the case of a drop hammer, as the pile is driven and the resistance proportionately increased, the height from which the hammer can be dropped and its consequent effect also increases, so that the adjustment of the two might be called practically automatic. The force of the blow, however, is limited by its destructive effect upon the pile, and so much time is lost between blows that the work is slow. The number of blows obtainable—six to ten per minute—is not sufficient to prevent the settling back of the earth, as is the case with a steam hammer working rapidly. A light blow of the latter is, therefore, as effective as a heavy blow of the former.

There are essentially two distinct types of steam pile-driving hammers. In the first, the steam, acting under a piston, raises a weight which is allowed to drop by gravity. The stroke, being necessarily limited to keeping the apparatus within practical size, ranges from 20 inches to 30 inches. This being also the height of the fall, a heavy drop weight must be used to secure a sufficient force of blow, especially that there is probably a slight retardation of the fall, due to back pressure of the steam against the piston during the period of exhaust. Notwithstanding this, a speed of about sixty blows per minute is obtained. This is a



A. A. GOUBERT'S STEAM PILE-DRIVING HAMMER

great improvement over the six to ten of the ordinary drop hammer; but the considerable size of the hammer is a drawback in this type, a 3,000-pound hammer delivering a blow of 7,400 foot-pounds, being over 12 feet high.

In the second type a double-acting steam cylinder is used. After lifting the weight the steam is reversed and applied on top of the piston to propel the hammer downward at a greater speed than would be obtained from gravity alone. A shorter stroke can be used and a greater number of strokes obtained. A hammer of this type can be used easily to deliver 200 blows per minute.

In analyzing the performance of this type, it is a common error to figure the pressure upon the piston area as if the piston were a mass, the arresting of which produces an impact reducible to foot-pounds. This is erroneous; the action of the steam upon the piston is only to propel it at a velocity proportionate to steam pressure and to the freedom of its admission to the cylinder; and as this force is applied to a falling weight, its effect is to accelerate the velocity of the fall, so that for a given pressure the greater the weight, the greater the dynamic effect of the blow.

On the other hand, the greater the velocity, the greater the impact, and this is in proportion to the square of the velocity at the end of the fall; if we double the velocity, the impact is four times as great.

As a concrete example, if we suppose a 1,000-pound weight falling 2½ feet, the velocity at the end of the fall will be 12.6 feet per second and the impact 2,466 foot-pounds; but with double the velocity the impact will be 9,864 foot-pounds, equal to the same weight of 1,000 pounds falling from a height of 10 feet.

If the moving parts are of light weight, the hammer will be very ineffective. For this reason it is customary to attach a heavy weight or "ram" to the lower end of the piston rod. This weight is raised by the pressure of the steam under the piston, and the admission of steam reversed to the top of the piston propels the weight downward at great velocity to strike the blow.

The work is very severe, especially when driving steel sheet piling, and might be compared to a hammer

striking a full blow on a steel anvil. The concussion has a tendency to loosen all bolts, nuts or fastenings. Such should be eliminated as far as possible from the moving parts. The percussion reverts to the piston rod, which, being of comparatively small area, is strained much beyond its elastic limit. Repeated blows cause it to fracture as if it were of glass, often after only a few hours of work. The delicate valve mechanisms are subject to continual breaking, and the hammer may be more often undergoing repairs than in actual service. The advantages may be more than offset by continual trouble. It is true that this criticism applies in a measure to the steam drop hammer of the first type, but in a much greater degree to the steam-driven hammer of the second type.

It is, therefore, necessary, in order to secure continuous service, that a steam-driven hammer be constructed with the fewest possible parts liable to jar loose, such as bolts, nuts, cotters, valve parts, etc. All such parts should be in plain sight during operation, so that the loosening is easily detected and remedied before the occurrence of actual damage. The hammer proper or "ram" should be free from other parts at the moment of striking, so that the percussion cannot affect piston rod or valve gear. Its weight should be as great as consistent with the design, the work to be done and the pressure of steam. Its mass and sectional area of the striking part should be such as to easily absorb the reaction without straining the fibre of the metal, and, lastly, all parts should be of steel.

All these points have been well worked out in the construction of the Goubert pile-driving hammer, which we illustrate.

In this machine the cylinder, a heavy, solid steel casting, is the hammer that strikes the blow; it slides freely on guides which are part of the frame, and its mass is such as to readily absorb the effect of percussion. Its lower end or pene strikes upon a loose anvil or dolly block, also of steel, that rests on top of the pile, and the pene is of such large area as not to be injuriously upset by the effect of the repeated blows.

The piston and the piston rod are stationary and rigidly connected to the valve chest, which, in its turn, is securely bolted to the frame; channels bored through the piston rod admit the steam alternately above and below the piston. The admission of steam is controlled by a rotary valve in the chest above the piston rod. This valve is actuated by a radial arm, to the end of which is hung a heavy plunger.

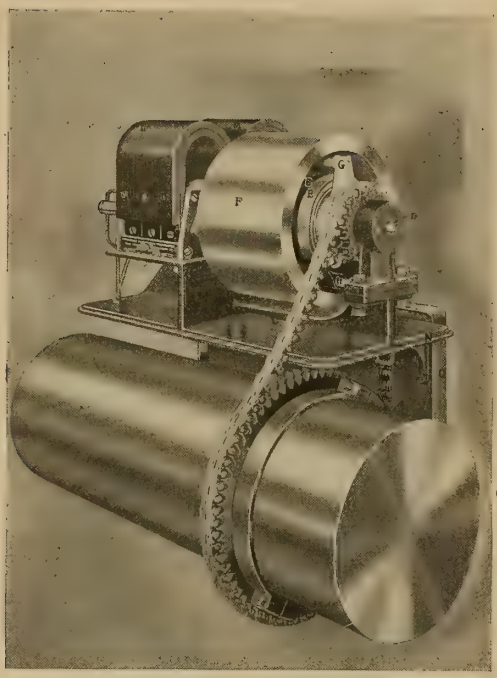
The cylinder has no permanent connection with the valve gear. At the end of the up stroke it strikes the plunger, rotating the valve and admitting steam under the piston; the cylinder is propelled downward and strikes the blow. The percussion causes the plunger to suddenly fall, thereby reversing the valve, opening the exhaust and admitting steam for the up stroke. A buffer spring limits the fall of the plunger. The parts are all heavy, of ample strength, easily accessible and renewable.

All parts, including the frame, are of open-hearth steel, and practically indestructible.

The frame is arranged to slide on leaders, if required, and an eye is provided on the top of the chest for suspension from a derrick.

The length of dolly block is such as to permit of driving two interlocking sheet piles at the same time, and it is made in the form of a cross, to readily drive corner piles. It is also arranged to take in round piles from 9 inches to 20 inches, according to size of hammer.

This hammer is manufactured by A. A. Goubert, 90 West street, New York City, to whom all communications upon the subject should be addressed.



THE HUTCHISON TACHOMETER

A Marine Tachometer

FEW subjects awaken a more general public and professional interest than speeds of ships. Since the speed of every power boat is a function of the velocity of its screw or shaft, a device which will continuously indicate these velocities, not only in the engine room, but on the bridge, in the conning tower, captain's cabin, or anywhere desired, holds an important place among indispensable navigating instruments.

A simple, reliable and precise instrument is the Hutchison marine tachometer, which is built by the Industrial Instrument Company, New York and Chicago, and the construction of which, as well as its relation to safety and economy of navigation, will be briefly described below.

The history of marine accidents shows in a striking manner the liability of signal apparatus to become deranged, or of confusion in the interpretation of signals, the result of which is that the engines are starting ahead when they should reverse, and *vice versa*.

But it is not only necessary to avoid catastrophes: the majority of ships must pay dividends. Neither can yachts and warships be run in total disregard of economy. There is an economic rate for every ship, and although other factors may necessitate running at other than these critical speeds, there is a certain definite speed which should be maintained. The tachometer shows the corresponding R. P. M., or makes evident instantaneously any deviation from this desired speed. It makes possible a finer degree of control; hence ultimate economy.

When two or more turbine-driven screws are used, the indication of speed of each enables the engineer to promptly and easily bring them up to the exact speed desired. The operation of the apparatus is as follows:

Clamped around the propeller shaft *P* is split sprocket *A*. Rotation is imparted to driven sprocket *B* by the Morse silent chain *C*. Sprocket *B* is not keyed to shaft *D*, but is rotatably mounted thereon. Two oppositely coiled flat spiral springs *E-E'* transmit the rotation of *B* to fly-wheel *F* and shaft *D*, one end of each spring being attached to the sprocket *B*, and the other end of each to fly-wheel *F*. Hence any irregularity of rotation of *B*, caused by variations in the angular velocity of shaft *P*, is smoothed out by *E-E'*, imparting to *F* and *D* a constant resultant speed. The springs are protected against breakage from sudden reversal of *P* by radial arm *G* engaging pin *H* attached to fly-wheel.

On the inside face of fly-wheel, at the end opposite from that occupied by *E-E'* are cut gear teeth. These engage two pinions, which actuate magnetos.

One of the pinions is keyed to inductor shaft of its magneto *M*, while the other is so mounted that when

the direction of rotation of main shaft *P* is "ahead" the inductor of magneto *L* is in the exact rotative relation to its armature and pole shoes as that of magneto *M*. The current from *L* is, therefore, in absolute phase with that from *M*. But when *P* is reversed in rotation, the second pinion rotates idly on shaft of magneto *L* until it has traveled 90 degrees before rotating same. This causes the inductor of *L* to assume an exactly opposite relation to its armature and pole pieces as obtains at the same instant in *M*, and hence the current from *L* is 180 degrees electrically out of phase with *M*.

We have, therefore, two wires from *L* and two from *M* running to the indicators. At "ahead" these circuits are in phase. When *P* rotates "astern," one is 180 degrees electrically out of phase with the other.

The indicators withstand continued vibration, and are waterproof, rust-proof, and not affected by the rolling or pitching of the ship.

The smaller cut shows the pilothouse type of indicator. It has no compass-deflecting parts, and may be placed in proximity to the compass without affecting either. Alternating current is used in this system in exceedingly small quantity. Therefore, no compass trouble from leading in wires is possible. In fact, with a thorough comprehension of every marine requisite, every contingency that can arise has been provided against.

The indicator has two coils—a moving coil to which the pointer is attached, and a fixed or field coil. The moving coil is connected electrically to one of the magnetos, the fixed coil to the other. When the two magnetos are in phase, the pointer is deflected to the right, indicating R. P. M. ahead. When they are out of phase, the pointer is deflected to the left, indicating R. P. M. astern. The faster the shaft *P* turns in either direction, the higher

TACHOMETER INDICATOR

the voltage generated, and the greater the deflection of the pointer calibrated to conform thereto.

The Hutchison marine tachometer is guaranteed free from defective material and workmanship for a period of three years, and parts will be replaced free of charge if returned because of such defects.

The calibration is guaranteed to remain permanent for a period of at least one year, with full assurance that three years will find it still accurate within one per cent.

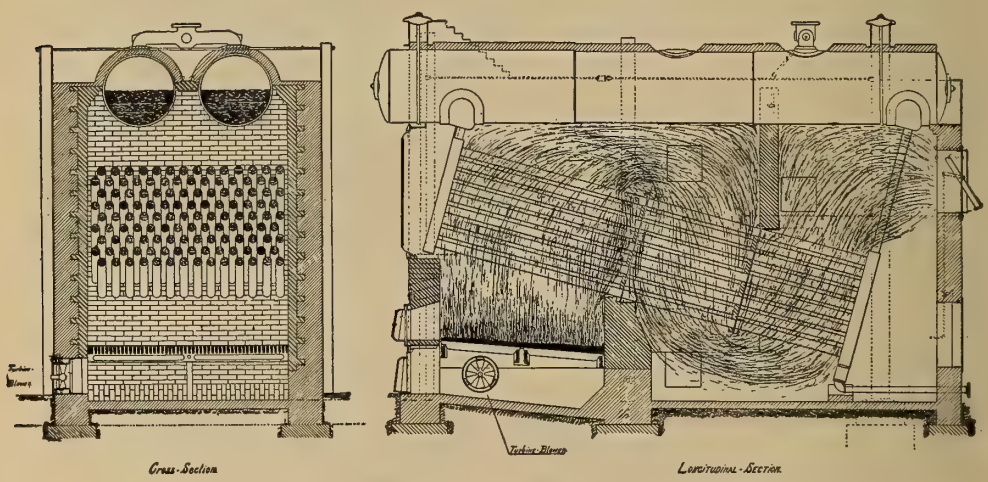
Steam Engineering

A pamphlet, entitled "Arrangement of Engine Cylinders to Produce Uniform Torque," has just been issued by the American Engine Company of Bound Brook, N. J. This pamphlet contains typical indicator cards taken from the American Ball Angle Compound Engine, and also a derived crank effort diagram. This diagram shows that this type of engine produces a torque which is nearly as uniform as that given by steam turbines, while the steam consumption is considerably less than that of turbines. The booklet also contains a discussion of the crank effort diagram and will be sent free upon application.

Mechanical Draft

AMONGST the various new applications of the steam turbine perhaps one of the most interesting is its recent use in connection with mechanical draft, where it is largely replacing the older methods of belt or engine-driven fan and the aspirator or steam jet. For this purpose there has been developed a blower consisting primarily of two elements, viz., the fan and the turbine. The manner in which these two are combined to form a single compact unit is plainly shown by the accompanying illustration. A hollow-cored steam chest having a half-inch steam inlet holds the nozzles. From these the steam impinges directly upon the buckets cast by a special process into a bronze ring to the inner periphery of which the fan proper is attached. The bearing consists simply of a bronze bushing, which revolves on the fixed hollow steel shaft, the end thrust being taken up by tempered steel surfaces. A cap screwed over the end of the hub makes the bearing dust-proof, while complete protection is afforded by enclosing the entire rotating element in a cast-iron casing.

The "Typhoon" turbine blower can be placed directly in the boiler wall, as shown in the illustration, thereby saving valuable floor space, allowing separate boiler control and reducing repairs, supplies and attention to a minimum. Operated automatically by the damper regulator, the turbine blower forms a unit of great flexibility, whose steam consumption is exceptionally low and whose broad range of air delivery and pressure makes possible the proper and highly efficient combustion of all low-grade fuels, giving, at the same time, a marked increase in the capacity of the boiler. Furthermore, as the exhaust steam from the turbine passes with the air into the ash pit and through the fuel bed, this method retains the advantage of preventing any tendency of the coal to clinker.



THE TYPHOON TURBINE BLOWER APPLIED TO A WATER-TUBE BOILER

Any further information regarding the system in its various applications can be obtained from the L. J. Wing Manufacturing Company, 91 West street, New York City. The blower is made in four sizes, viz.: 12, 16, 20 and 24 inches, suitable alone or in combination for any size boiler. The company's latest bulletin, No. 6, gives complete descriptive details and data of the "Typhoon" turbine blower system for mechanical draft.

An Improved Core Drill

THE Terry Core Drill Company, of No. 40 Church street, New York City, have recently placed on the market a hand-power core drill which is designed for prospecting, foundation testing and for making wash borings. To determine, without washing, the character of soils or mineralized sand, special tools are provided with which "dry samples" can be obtained. This method of testing, particularly in placer deposits, is important, as the exact formation can be at once determined, whereas by the washing process the heavy or mineralized particles will not always wash to the surface.

They claim that the design of this drill is unique, as they have equipped it with a fly-wheel, which insures a uniform speed of the drill tools with the least exertion. This is an improvement which has not previously been taken advantage of in hand-power drills.

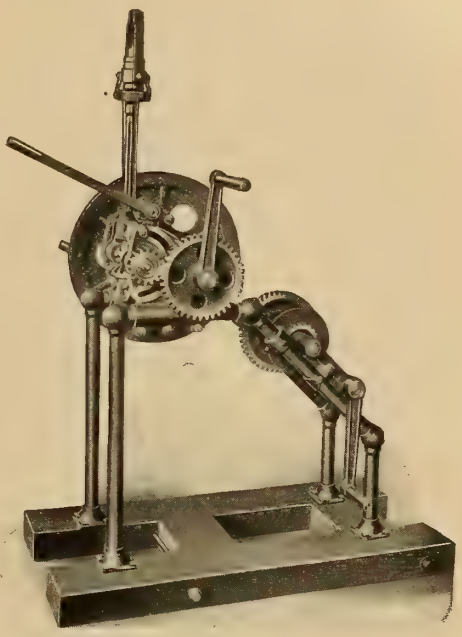
Furthermore, the drill has unusually long bearings for the spindle, which is a feature of all the drills designed by this company. These long bearings impart a steady motion to the drill rods, and prevents their lashing in the bore hole, thereby avoiding unnecessary breakage of the cores, increasing the speed of drilling and the percentage of core which is recovered.

The capacity of this drill is 300 feet, to which depth it will bore a 2¼-inch hole and cut a 1¼-inch core.

For mountainous countries, inaccessible to larger apparatus, and where fuel is difficult to obtain, it is particularly adapted. The shipping weight is 415 pounds, and the heaviest single piece (the fly-wheel) weighs 73 pounds.

The head swivels to any angle, and can be slid back on its frame to clear the bore hole when raising or lowering the drill rods or when casing is being driven.

A sensitive feeding device is used, which consists of a double drum with ropes extending to the water swivel and to which pressure is applied by a lever with a ratchet and pawl.



THE TERRY CORE DRILL

Mounted on the rear of the drill frame is a hand-hoist used for raising or lowering the drill rods and for driving casing through soil to bed rock.

Cut gears and phosphor bronze bearings are employed throughout, and all working parts are carefully and accurately machined, so that friction is reduced to the minimum.

A hand force pump is used, which supplies water to the bore hole.

For drilling operations more extensive than a hand machine is capable of undertaking, and when portability is essential to the work, a power attachment can be applied to this drill by substituting a pulley for the fly-wheel and a countershaft with a friction clutch to control the power. When so arranged it can be driven with steam, gasolene or horse-power.

When equipped to operate with power, it is capable of boring a 2¼-inch hole to a depth of 400 feet.

An Improved Jet Condenser

THE jet condenser is the oldest type of apparatus for producing a vacuum by the condensation of steam, although the idea of a surface condenser was soon evolved for situations in which water containing salt and other substances had to be used, as in marine practice. When pure water is available, however, the immediate contact of the water with the steam still remains as a most effective means of condensation, and its applications are numerous.

Curiously enough, the general arrangement of the jet condenser has remained much as it was first devised by Watt, the principal modifications having been the introduction of the dry air-pump and the various types of ejector condensers.

A radical improvement which has been introduced in the design of condensers of the jet type, however, is that which has recently been developed by the Wheeler Condenser and Engineering Company, of Carteret, N. J. The features sought to be obtained in this improved design may be considered under two heads: One being the maintenance of the counter-current principle, causing the steam to flow in the opposite direction to the water, thus compelling the hottest steam to meet the coldest water; and the other being the more effective mingling of the steam with the condensing water in such a manner as to facilitate very greatly the abstraction of the heat from the steam by the water.

The condenser, of horizontal rectangular form, is arranged so that the steam to be condensed enters at the bottom and passes back and forth on its way to the outlet above to the air-pump. The water enters at the upper right-hand corner and flows back and forth through pans, from which is dripping a shower directly across the path of the steam, so that it is impossible for any volume of the steam to pass to the air-pump without having traversed all of the sprays. It will be seen that this design effects a perfect contact of the steam with the water, and, at the same time, produces the counter-current flow by which the highest efficiency is secured. The design also prevents pocketing of air and insures the full efficiency of the whole apparatus, the assurance of which appears in the fact that with this condenser a vacuum of 28.75 inches of mercury is readily maintained.

A full description of this improved condenser, together with a discussion of the general theory of jet condensers, is contained in a booklet which may be had upon writing to the Wheeler Condenser & Engineering Company, Carteret, N. J.

Water Softening

Summing up their practical experience with water softeners they have installed for railroads, the American Water Softener Company, 1011 Chestnut street, Philadelphia, Pa., say: "Water softeners save enough coal to pay the interest on the cost of installation and the extra cost of treating the water. Besides this saving, there is, 1st, a better train movement and less boiler failures on the road; 2d, a certain water supply; 3d, heavier trains hauled for the same or less expenditure for coal. Before the installation of water softeners as many as three boiler failures in one day on the same train was a frequent occurrence. Trains were reduced to go over the road. Many locomotive deadhead miles were made and more coal was burned with less results, due to leaks and cracks in the boilers. It is difficult to put into exact figures in dollars and cents the saving on the mechanical department side. The number of broken staybolts is decreased. In renewing flues, from one to three bucketsful of loose scale are now removed when formerly there were from one to two drayloads per locomotive. The effects due to corrosive action of untreated water are, in a large measure, removed, such as leaky mud rings, corners, seams, round staybolts, flues, tanks, by correcting the cause.

News Items

Mr. L. J. Wing has severed his connection with the L. J. Wing Manufacturing Company, and Mr. Ernest J. Fieux has been elected president of the company. The company is engaged in the manufacture of the "Typhoon" turbine blower, and of disc fans, etc., for all purposes of forced draft, and is prepared to consider the installation of equipment for such service of the highest class. All communications should be addressed to the company, at No. 91 West street, New York.

Messrs. Geo. M. Brill and Horace C. Gardner have formed a partnership under the name of Brill & Gardner. They will continue the engineering and architectural work heretofore conducted by Mr. Brill, while Mr. Gardner has gathered more than twenty years' experience, during which period he was active as manager of the construction and mechanical departments of Swift & Co.

Mr. Paul M. Chamberlain has opened an engineering office at 1522 Marquette Building, Chicago, Ill.

He was graduated from Michigan Agricultural College in 1888, and from Cornell University in 1890. After having done practical work with the Brown Hoist Company, Cleveland; the Frick Company, Waynesboro, Pa., and the Hercules Iron Works, Aurora, Ill., he became assistant professor of mechanical engineering at the Michigan Agricultural College; then, at the opening of the Lewis Institute in Chicago, he took charge of the engineering work and brought it up to its high standard. Doing much consulting work with special reference to power production and factory methods while connected with that institution, he at last resigned that position to become consulting engineer for the McCan Mechanical Works, Los Angeles. Later on he went with the Under-Feed Stoker Company of America; he specialized on the study of boiler-room equipment, economy in fuel burning and smoke abatement for a period of two years and a half. He will devote his time to new designs and improvement of existing conditions.

To handle the increasing business in hydraulic apparatus, Watson-Stillman Company have made several additions to their sales department. Mr. Edwin Stillman has entered the same, and takes care of the business in New York State, while Mr. Frank C. Clark attends to the affairs in the South. The direct representation in the Orient is in the hands of F. W. Horn, of Yokohama.

The Cutler-Hammer Company, of Milwaukee, has recently erected in New York City a five-story building, covering a plot of about 100,000 square feet, for the manufacture of its electrical specialties. Alternating current for light and power purposes is furnished by the New York Edison Company, but the factory also possesses a complete equipment for transforming this alternating into direct current. Provision for an isolated steam-driven electric plant is made. The modern sprinkler system, the electric lighting system, the substantial construction and the well-chosen situation of the building, make it one of the finest factory buildings of New York. Design and construction of the building are the work of the Worden-Allen Company, of Milwaukee, whose success in construction work has led them to open offices in New York and Chicago for their clients' accommodation.

Through a mistake, the crane shown in the lower cut on page 224 of this magazine (January number) was ascribed to the McMyler Manufacturing Company, of Cleveland, Ohio. The bridge crane illustrated in this cut is the work of the Brown Hoisting Machinery Company, of Cleveland, and is among the largest coaling cranes ever built.

THE LATEST CATALOGUES

In writing for Catalogues, please mention Cassier's Magazine

Fans

BUFFALO FORGE COMPANY, Buffalo, N. Y. Catalogue No. 197 of this firm deals with heating and ventilating appliances for public and industrial buildings. The requirements of various situations are pointed out and the machines filling all these needs illustrated and described in detail. The 150-page book is divided into four parts: I. and II., devoted to applications, and III. and IV., to appliances. The catalogue contains also valuable tables compiled from the experience of experts.

Cutting and Welding Apparatus

AMERICAN OXYHYDRIC COMPANY, Milwaukee, Wis. Interesting booklet describing and illustrating the oxyhydric process, the machinery involved in it, reproduction of the application of the process and its results. Also, consumption tables and illustrations of the company's plant.

Coal Cutters

JEFFREY MANUFACTURING COMPANY, Columbus, Ohio. Cutting machines for electric and compressed-air operation are described and illustrated which are designed to do severe work; also, self-propelling trucks for shortwall coal cutter, electric mine locomotives and rotary drills.

Thermit Repairs

GOLDSCHMIDT THERMIT COMPANY, New York. A booklet entitled "Thermit Repairs" illustrates various applications of this welding material. Rails, anchors, water-wheels, crank-shafts, steel hammers and fly-wheels have been successfully welded. Some of this work was done at the shop of the company in Jersey City, N. J.

Transformers

PITTSBURG TRANSFORMER COMPANY, Pittsburg, Pa. Bulletin 1,098 contains handsomely illustrated descriptions of the self-cooled, oil-insulated transformers built by this firm, which, after having used both core and shell type designs, has now specialized on the core type. The illustrations show the simple and rugged mechanical design of these transformers, whose constructions are seen in the pictures.

Electrical Indicating Machinery

WAGNER ELECTRIC MANUFACTURING COMPANY, St. Louis, Mo. A vast variety of meters is described in Bulletin 84: voltmeters, ammeters and wattmeters for both direct and alternating currents; for the latter, also, power factor meters, polyphase ammeters and polyphase wattmeters. All information is detailed, and the illustrations give proof of excellent design of the indicators.

Power Pumps

GOULDS MANUFACTURING COMPANY, Seneca Falls, N. Y. Handsomely illustrated catalogue devoted to plunger, mine-sinking, piston vacuum, plunger vacuum, rotary force and fire pumps, centrifugal, air-pressure and vacuum pumps, boiler-feed and electric house pumps, various electric switches and valves, friction-clutch coupling, etc. The booklet includes also directions for assembling, piping and operating power pumps and a number of tables containing valuable information.

Storage Batteries

WESTINGHOUSE STORAGE BATTERY COMPANY, Boonton, N. J. Bulletin "I." deals with ignition batteries for internal-combustion engines for automobiles, gasolene launches, etc. The Bijur, Reserve and Plante sparker are described and their capacities given. Bulletin "V." is devoted to several types of batteries for electric vehicles, which apparatus are shown and described in detail.

MANUFACTURING NEWS

Furnaces

Rockwell Furnace Company, New York. Bulletin G of this company contains the illustrated description of the Rockwell under-fired furnace, designed for hardening, tempering, annealing and case-hardening of machine parts and tools, dies, screws, cutters, springs, etc. Oil or gas fuel is used. This applies also to the over-fired furnaces built for working nickel, chrome, high-speed steel, brass, etc. There is also the illustration of the portable oil-fired furnace, and of an oil or lead bath tempering furnace.

Tungsten Electric Lamps

General Incandescent Lamp Company, Cleveland, Ohio. Bulletin No. 6D treats of the Tungsten multiple lamps ranging from 100 to 125 volts, and consuming from 25 to 100 watts per hour. All details relating to these lamps, as well as the relations between intensity, voltage, current consumption and prices, are found in the booklet.

Coal and Ore Transportation

J. M. Dodge Company, Philadelphia. Illustrated book covering the transportation of above-named materials, and describing the machines used for this purpose, i. e., cranes, hoisting towers, bridge tramways, direct unloaders, automatic railways, man-operated trolleys, car-dumping machines, etc.

Electric Meters

Westinghouse Electric and Manufacturing Company, Pittsburg, Pa. Circular No. 1181 covers the portable direct-current ammeters and voltmeters made by this concern. These apparatus are of small volume and weight, accurate and durably constructed.

Car Seats

J. G. Brill Company, Philadelphia, Pa. Catalogue containing illustrations of seats and seating materials for cars and waiting rooms, winner seats, motorman's seats, cushions and pressed-steel pedestals, etc.

Valves and Cocks

William Powell Company, Cincinnati, Ohio. Catalogue No. 9, of this company, contains an absolutely complete line of all kinds of valves, cocks, and similar apparatus, which are made by the above-named concern. To name a few of the firm's specialties: air, cylinder, steam guard, gas-engine indicator, steam-gauge and compressor cocks; gate, compression, by-pass, hydraulic, blow-off check, cross, throttle, radiator and whistle valves; wrenches, oiler-screw yoke tops, lubricators, grease cups, expansion joints and couplings.

Machine Tools

Garvin Machine Company, New York. Edition G of this firm's catalogue is devoted to the detailed descriptions of a number of high-grade tools which this firm makes, such as hand lathes, spring coilers, cutter grinders, surface grinders, milling machine tools, screw machine tools and attachments, friction and cone pulleys, countershafts, hangers, etc. The booklet contains also a number of well-compiled tables.

Injectors

William Sellers and Company, Philadelphia, Pa. Beautifully finished booklet devoted to the description of the widely-esteemed locomotive injectors and boiler attachments manufactured by the above firm. A number of standard apparatus are described in detail and prices are given. The book contains also a number of tables showing the capacities of injectors constructed by this concern.

Perforated Metals

Hendrick Manufacturing Company, Carbondale, Pa. Handsomely illustrated catalogue showing various patterns of the perforated plates manufactured by this firm for various purposes; for instance, revolving screens, bucket parts, etc. Beside the two-color illustrations the booklet contains a number of tables relating to varieties of perforations, wire weights, wire-gauge standards and some more useful information.

Coal-Handling by Electricity

IT has been estimated that the present annual production of coal in the world exceeds one thousand million tons, of which doubtless more than one-half is utilized in industrial operations. This means that between one and two million tons of coal has to be handled every day in the year, and that the ashes produced by its combustion have also to be handled, removed and deposited elsewhere.

Although a large part of the handling of this immense quantity of fuel is performed by manual labour, there has necessarily been introduced a variety of ingenious mechanical devices for substituting machinery for human muscle. In the original mining the coal must be handled to a large extent by hand, even if it is mined by machinery. It is hoisted to the surface by power, and, in the modern colliery, it is delivered by gravity into the cars in which it is hauled, also by power, to its destination.

Ultimately, however, it must find its way into some kind of a furnace, whre it is burned in order that the latent energy stored within it may be released as heat, and it is in this final handling that the latest developments of mechanical appliances of this kind necessarily appear.

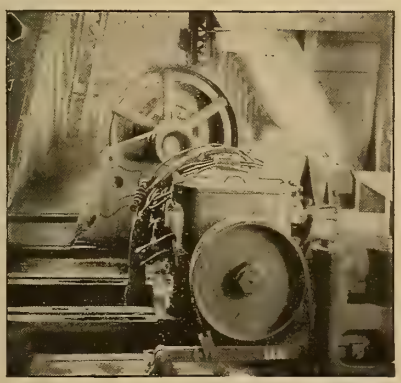
Formerly the coal was shovelled into cars by hand, and shovelled out again. If it was transported by water, it was shovelled into baskets in the hold of the boat and carried ashore at its destination, only to be again shovelled into bins for storage, and again transferred thence by shovel into the mouth of the furnace. Thus the two elements in the handling of coal, and of its residue, ashes, consist of shovelling and hoisting, these including the converse features of lowering and shovelling some more. It has always been hard and dirty work, and, in view of the enormously rapid increase in the quantity to be handled, it has become increasingly necessary that it should be wholly performed by machinery. This is more especially the case if we remember that all this immense amount is practically mined as used, and that, in the case of strikes, or other interruptions to production, the quantity in storage is speedily diminished almost to the vanishing point. Probably the greatest storer of coal is the British Admiralty, concerning which no definite figures are obtainable, but it is estimated that the railways carry a supply available for six weeks, or two months at furthest, and other industries a much smaller proportion.

This means that industrial establishments, power houses, iron works, and all the great coal-using industries must be equipped with coal-handling machinery, and to this necessity is doubtless due the improvment which has been made in this class of machinery during the past few years.

One of the most notable developments in this department of applied science appears in the rapidly increasing use of electric power for the operation of such machinery. Most of the large power houses are situated by the waterside, the fuel being brought in barges, from which it is hoisted into the overhead bins, and even if the transport is by rail, a similar hoisting equipment is necessary. In this department of work the electric hoist is rapidly displacing the steam-operated machine, and the advantage of a machine which can receive its energy through a wire, and which is so designed and constructed as to stand the difficult operative conditions involved in coal and ash handling, is so great that the electric hoist is superseding the steam engine. Such apparatus is manufactured with the same care and skill as is given to any other type of machine tool, with the effect that far better results are obtained than with the earlier devices, and, at the same time, with a smaller expenditure of power.

"HUNT" ELECTRIC HOIST

Direct Current, any voltage
Alternating Current, any frequency



No. 0250
Motor and Hoisting Drum Operating the Trolley on the Boom of the Steeple Tower. Load on the Rope, 6,000 Pounds

No. 0252
Motor Connected to Hoisting Mechanism Operating the Duplex Shovel of Steeple Tower. Height of the hoist 151 feet.

ELECTRIC HOIST EQUIPMENT IN A POWER STATION.

These hoists are simple and rugged in construction, and every hoist we send out is guaranteed to do the work for which it sold.

They are fitted with gear cases that enables them to stand any test of exposure to weather, dust or ashes, etc.

The gears have machine cut teeth and all parts are interchangeable.

Write for Bulletin F. 4, and also tell us the work you wish to accomplish, and we will furnish the hoist that will do it.

C. W. HUNT COMPANY

(ESTABLISHED 1872)

Main Office and Works: WEST NEW BRIGHTON, N. Y.

New York Office: 45 Broadway

Boiler Feed-Water

A STEAM BOILER has to encounter many enemies in the course of its daily work in the generation of steam, and some of these must be continually watched or they will get beyond the control of the engineer before he is really aware of it.

Of course, the boiler must be so designed originally that it will sustain the pressure at which it is to be worked, and that it shall not be exposed to high temperatures except at points where the metal is protected by water within. If it is properly built and set it should be reasonably free from stresses caused by unequal expansion and contraction, and this consideration applies also to the piping by which it is connected to the engines and other consumers of the steam which it makes. That proper provision be made for adequate and certain supply of water is fully realized by both designer and user, and these evident and reasonable requirements are, in the great majority of cases, properly met.

The question of water supply, however, includes another matter besides quantity. There must not only be plenty of water, but it must be of suitable quality for steam-making. Steam is practically pure water in the form of vapour, and this is what goes out of a boiler. Anything else which goes into the boiler with the water *stays there.* That means that if the water contains any dirt or mud in suspension, the boiler will become a receptacle for accumulations which, if not removed, will before long cause it to become choked up. It also means that if the water holds in solution any substances, such as calcium or magnesium salts, these will be precipitated and remain in the boiler also, until they are removed.

In the case of marine boilers which in the earlier period of steam navigation were supplied with sea water containing a large proportion of salt as well as of other substances in solution, the importance of keeping the proportion of salt down by "blowing off" was fully realized, until the introduction of the surface condenser made it possible to use pure water in the boilers.

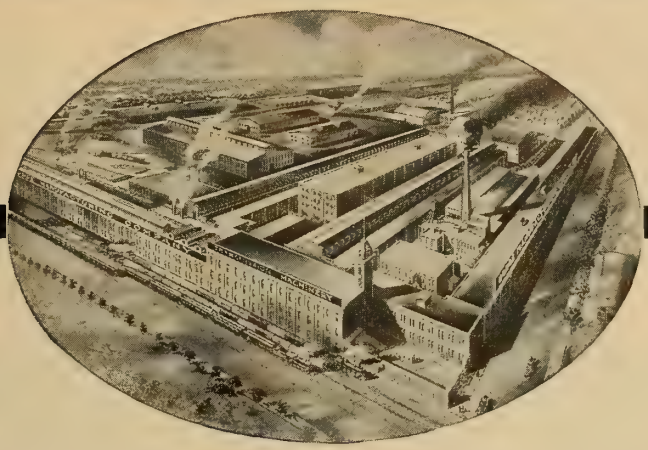
Formerly the general custom in steam boiler practice for stationary plants was to maintain a periodical examination of the interior, followed by a cleaning of the boilers, both as regards mud and scale. It is still wise to make periodical investigation of the internal condition of boilers, but it is now very generally understood that the true way to get the best results is not to allow mud and scale to accumulate inside, but to remove all such impurities from the water before it enters the boiler. The best way to keep a boiler clean is to put only pure water into it.

So far as the methods of purifying boiler feed-water are concerned, these must naturally depend largely upon the nature of the impurities.

Mud can generally be removed by giving it an opportunity to settle out; which means that the heater or purifier employed must be large enough to avoid too rapid a flow of the water in passing through it.

Carbonates of calcium and of magnesium, which will form scale in the boiler, may be removed by heating the water to a temperature which will drive off the carbonic acid; while sulphates require a somewhat higher temperature. Treatment with lime and soda will also remove these impurities, the soda converting the sulphates, chlorides, etc., into carbonates, and the lime precipitating them.

It is thus entirely possible to remove, at a very moderate cost, all the impurities which, if delivered into the boiler, act to reduce its efficiency, shorten its life, and diminish its safety. Satisfactory apparatus for this purpose is manufactured and installed by well-known engineering firms, and there is no reasonable excuse at the present time for obliging any steam boiler to be fed with impure water.



Our Enlarged Factories

24 Acres of Floor Space

Here's Proof of the Wonderful Growth of the Dodge Idea

In Power-Transmission Machinery

THE picture above shows the Dodge plant today; the one at the bottom of the page, the cradle of the company, in 1879. A growth based on *reasons.* In the designing of the Dodge Line of Power-Transmission Machinery, there was one thing that took precedence over everything else—Safety. *The safeguarding of life and property* has ever been a cardinal principle of the Dodge Idea; With the result that the Dodge Line always complies with the latest factory laws on the subject.

The Dodge combination of safety, economy, standardization, interchangeability, and reduction of friction, means a great deal to you, Mr. Manufacturer.

It means greater freedom from accident risk. It means a saving in time and expense in installation, and a saving in power every day.

With the Dodge Line, you have a shop standard in transmission equipment that you cannot possibly obtain in any other line. It insures simplicity in shop accounting; it insures to you a quick delivery through the nearest of ten branch houses, or the nearest of over two hundred dealers carrying the Dodge Line in stock

It was these exclusive Dodge features that made the Dodge Line the standard of the great Buick Motor Company, the largest automobile factory in the world; Postum Cereal Co.; Kellogg's Toasted Corn Flakes Co.; National Electric Lamp Co.; Cleveland Worsted Mills; I. E. DuPont de Nemours Powder Co.; Corn Products Refining Co., and hundreds of others.

We can do as much for you. We want to give you the benefit of our 27 years' experience in power-transmission engineering on any transmission problem you may have. Our engineering department is at your service always, and our manufacturing facilities are up to the minute on everything—from a half-pound collar to a 100-ton fly-wheel.

Our Magazine Free.—"The Dodge Idea," our illustrated magazine, during 1910, will contain many mechanical articles of interest and value to manufacturing executives and heads of mill and factory departments. We want every owner, manager, superintendent, master mechanic, chief engineer and purchasing agent of power-using plants on the mailing list. Send the coupon today.

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"Cradle of the Dodge Mfg. Co."

Photograph taken in 1879.

The Man and the Machine

THE old idea of labour was that which assumed that there was something especially dignified and creditable in an exhibition of muscular effort. Somehow, it was thought that when a man had exerted the maximum force of which he was capable until he was practically exhausted, he had done something particularly worthy of commendation, and that he was a good workman, even if he had really accomplished something of comparatively small value. Fortunately, this primitive conception of work has been greatly modified, and the change has been effected very largely by the introduction of what has rather ineptly been named "labour-saving" machinery.

When mechanical devices were first introduced to assist animal effort in the accomplishment of work it was believed in some quarters that the dignity of labour, so-called, was being infringed by the use of such unwarranted auxiliaries. Gradually certain simple appliances, such as the lever, roller, tackle-block, etc., were conceded as properly belonging to the tools of the workman, and thus gradually the various kinds of machines entered the service of man.

At first mechanical appliances were used only when the power of unaided human effort was unable to effect the desired purpose, and there was no thought of the advantages of higher efficiency which might be attainable. Later it was found that the machine might often be used to greater advantage than the man, even though the object were within the capacity of the latter. Gradually the aim of the designer of the machine became the production of a device which should always be more efficient than the man, and should be acting continually to diminish the total amount of laborious effort demanded of human muscle.

In the heavy work of lifting burdens the modifications of the lever, such as the incline, the windlass, the tackle-block, have necessarily long been employed, and in the modern effort to replace the man by something more efficient the development of the perfected chain hoist forms a most interesting chapter in the history of the replacement of the man by the machine. Even the early type, the differential block, was more effective than the rope tackle which had preceded it, while the later improved devices, the duplex and the triplex, raised the efficiency of the machine to a higher point than is usually found in the man himself.

At the present time much attention is being paid to the determination of the efficiencies with which various industrial operations are effected. By careful observation, and by the conduct of methodical time studies, it has been found practicable to determine, with a fair degree of precision, the time which should reasonably be required for the execution of a given task. Taking this as a basis, it becomes possible to compare with it the actual time expended by different men, and thus to reduce all of them to a standard basis of efficiency. In actual practice this method has shown itself of much value in improving the efficiencies of the workmen and of raising the general standard of performance in manufacturing operations. At the same time, the basis upon which such efficiencies are computed is not absolutely definite, being the result of the judgment of the individual making the time studies, and being subject to revision under changed conditions. With the machine, however, the question of efficiency is mathematically exact, being the relation of the actual number of foot-pounds of energy put into the apparatus to the actual number of foot-pounds delivered.

There are few men who reach an efficiency of 80 per cent., even upon an assumed basis for the computation of the perfect result; but this result has been obtained beyond question with such an apparatus as the triplex chain block as positively determined.

Manufacturing News

Pushing Foundations into the Ground

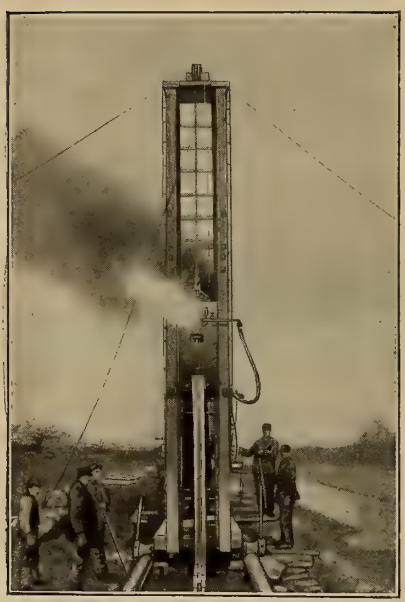
THE demands of modern commerce and manufactures leave the engineer and contractor small opportunity for the selection of the soil upon which their works are erected. If there be rock, or hard pan, so much the better; if not, the foundation must be made by the use of piling of some kind, driving wooden or metal legs into the ground to carry the load to be erected upon them.

The idea of a pile foundation is very old; the pre-historic lake dwellers of Switzerland managed in some way to force the trunks of trees into the mud, and thus support their houses far enough from the shore to insure safety from the wild animals at night. The land which the Hollanders have won from the sea contains an underground forest of timber, driven into the soft made-ground by primitive machines using heavy weights raised by human effort and falling at extended intervals. Later engineering developments have improved the pile driver to the extent of using mechanical power to lift the weight and to handle the material; but it has remained for recent times to substitute a new method for constructing pile foundations.

When a heavy weight is allowed to drop upon the head of a pile a certain blow is produced, forcing the pile a distance into the mud, according to the resistance. Before the next blow can be delivered, the pile has stopped and the frictional grip of the soil has effected its hold upon the surface of the trunk, and the resistance must be overcome again and again with each successive blow. This is the old way of driving piles.

There is a new way, however, a way based upon the principle that the time element is a feature which can be utilized: by replacing the heavy and infrequent pounding of the primitive pile driver by an automatic machine delivering a succession of blows with such rapidity that each blow falls before the movement caused by its predecessor has ceased. In this way an effect which is practically continuous is obtained, so that the pile may be said to be *pushed* into the ground, and when the machine is stopped the earth grips the pile firmly and holds it securely.

In designing a machine to be operated upon this principle there are a number of points to be considered, and in the Arnott pile hammer, driven by steam or compressed air, and manufactured by the Union Iron Works, of Hoboken, N. J., an exceedingly effective and convenient



PILE HAMMER MADE BY UNION IRON WORKS, HOBOKEN, N. J.

pile driver has been produced. The Arnott pile hammer is wholly self-contained, consisting of a plain cast-iron body with a cylinder and valve chest in the upper portion, enclosing the ram and valve rod below. The opening is formed at the bottom with jaws to fit over the top of the wooden or steel piling, or with a removable base for round piling. The jaws permit the insertion of pile caps for all makes of steel piling.

The hammer is operated by the pressure of the steam or compressed air, both on the up and down strokes, the force of the pressure being added to the weight of the ram. The piston and rod are made in one solid steel forging, the ram head being of solid steel keyed securely to the rod, the ram thus being formed of the piston, piston-rod and ram head.

It is obvious that such a self-contained piece of mechanism is extremely adaptable to varying conditions. The old type of pile driver, with the accompaniments of long guides and fall, demanded much more of an equipment for its use. The Arnott hammer may be held in fixed leaders of a standard land or floating pile driver, or it may be suspended from the boom of a derrick or a locomotive crane, and thus moved along from pile to pile as far as the reach of the crane extends. The weight of the entire apparatus being proportioned to the work which it is capable of performing, renders it unnecessary to do anything except to suspend the hammer above the pile to be driven and bring to it the pipe conveying the steam or compressed air. In some cases, where a long line of sheeting is to be driven, as in the construction of a dam, the hammer has been successfully operated while swung from the cableway, or even from a wire rope by means of a chain-block.

An example of the Arnott pile hammer as used for driving triple-lap Wakefield piling for reinforcing the banks of the Erie Canal, is shown in the cut, this being a No. 4 hammer purchased by the State of New York. Numerous other illustrations of the adaptability of the hammer are given in Catalogue No. 2, together with other useful information of value to contractors and engineers, this catalogue to be obtained by writing to the Union Iron Works, Hoboken, N. J.

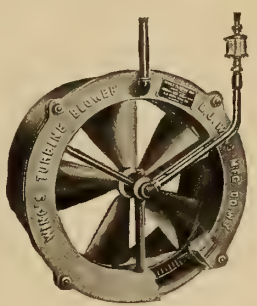
Mr. George U. Poole, manager of the Boston branch of the Dodge Manufacturing Company, in his lecture before the Mechanical and Electrical Society of the University of Maine, on Thursday afternoon, February 26, spoke on the manufacture of pulleys and castings and on methods of transmitting power by means of both belt and rope drives. The exceedingly interesting lecture was illustrated by especially well-chosen slides. Mr. Poole was very ably assisted by Mr. O. E. Humphrey, a mechanical engineer, of Bangor, Me. After the lecture, Mr. Perley Palmer, a Maine alumnus, spoke interestingly to the society. Also, at this meeting, Bigney, '10, gave a report from the committee on the Boston trip, to be taken by the society during the spring.

The General Electric Company, of Schenectady, N. Y., has published an attractive and valuable booklet on Gasolene-Electric Plants for Lighting and Power, which deals with gasolene-electric generator sets and tungsten lamps. These appliances enable the progressive man living in the country to avail himself of electric power and light, which otherwise he must probably miss. All the important applications of electric energy in the country, such as for pumps, creameries, vacuum cleaning, heating, threshing, etc., are dealt with, and numerous interesting details regarding these machines, which are exclusively products of the General Electric Company, given. The number of this publication is 4707.

A booklet describing the various classes of dryers used in all industries in which raw materials or finished products have to be dried before using them in the manufacture of some product or shipping them, has been published during the month of February by the Ruggles-Coles Engineering Company, of 50 Church street, New York. The book deals at length with the six regular types built by the above-named concern for various materials, as sand, stone, kaolin, ochre, agricultural products, nitrates and carbonates of soda and potash, etc., and a number of photographic and sectional views of the drying apparatus enable the reader to form a clear picture of the features and requirements of such machines. On the whole, this booklet is more than a mere catalogue, in that it is one of the few publications which are now brought out on this important subject, which is a very prominent one with a number of great industries, as road-making, ceramic industries, and such industries as are occupied with the production of the chemical materials specified above. The builders of the apparatus described in this publication will gladly send a copy of same to any one interested in the subject.

The Typhoon Blower

IN connection with the important articles upon Power Plant Wastes which have appeared in recent issues of this magazine, we desire to make a correction. On page 322 of the issue for February, 1910, reference is made to the fact that "turbo" blowers were installed to remedy defective draft. As a matter of fact, the blowers which were used in this instance were the well-known "Typhoon" turbine blowers manufactured by the L. J. Wing Manufacturing Company, of 91 West street, New York, this ingenious and effective machine being a combination of the steam turbine and the disc blower, combining the simplicity and power of the steam turbine as a motor with the disc fan as a means of producing a forced draft.



"TYPHOON" TURBINE BLOWER

The "Typhoon" turbine blower, as illustrated herewith, is the apparatus referred to in the last issue of this magazine as applied to a water-tube boiler, and an inspection of this simple and effective device will show how the combination of steam turbine and blower is constructed.

Among the most important appliances used by railways for lifting, clearing railroad tracks, etc., are the lifting magnets, which are sometimes constructed with a capacity of 100 to 150 tons. A detailed description of a lifting magnet, with several excellent illustrations, has just been published in the form of a twelve-page folder by the Cutler-Hammer Clutch Company, Milwaukee.

Cameron Steam Pumps

SEVERAL years ago, when the discussion about the Panama Canal was at its height, it was pointed out that there was more fuss about the undertaking than it really demanded, and that there was nearly if not quite as much engineering work going on in the midst of New York City as was under consideration at the Isthmus. Since that time the amount of engineering and construction under way in New York has increased rather than diminished, and one of the undertakings which has been recently developed is that of the new municipal building, to be erected near the Manhattan entrance of Brooklyn Bridge.

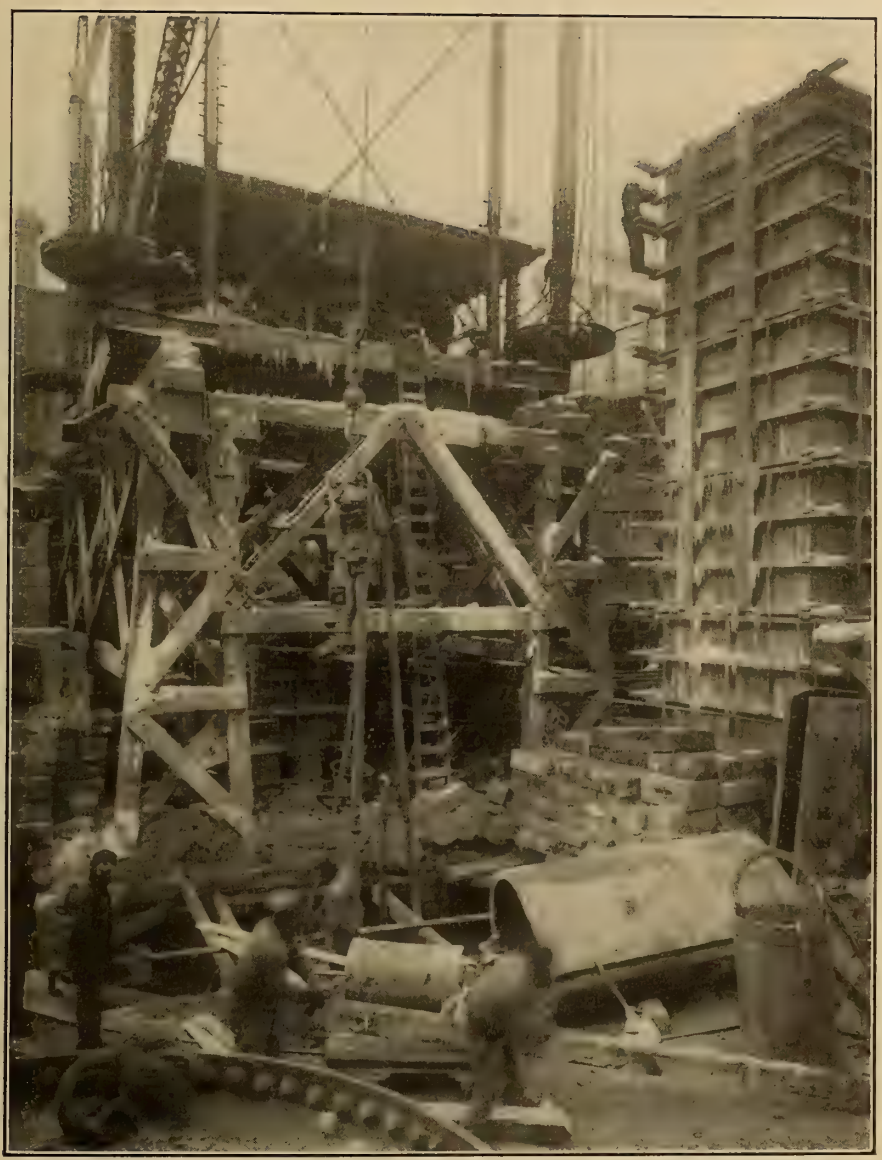
The foundation work upon this building involved some difficult caisson sinking, and in this work the Cameron steam pump showed its adaptability in a marked degree. One of the accompanying illustrations shows the manner in which a Cameron sinking pump was suspended from the hook of a derrick, so that it might follow up the work continuously and keep the pit free from the constantly invading water.

Work of this sort must not be retarded by weather conditions, and the other illustration shows the manner in which the engineering operations were conducted in the sinking of caissons, in the shoring up of adjacent foundations and in the erection of structural steel work while the air was at a temperature near the zero point.

These caissons had to be sunk to the solid rock, which was found at points about 30 feet below the surface, and the photographs indicate the manner in which such an undertaking is conducted in the midst of the busiest portion of the metropolis. In the distance is seen the covered way of the entrance to the Brooklyn Bridge, and beyond are visible outlines of the cupola of the City Hall and the dome of the Post Office.

Under former conditions and meth-

WORK ON FOUNDATIONS OF NEW MUNICIPAL BUILDING, NEW YORK, DURING ZERO WEATHER



SINKING PUMP USED IN FOUNDATION CONSTRUCTION WORK, MUNICIPAL BUILDING, NEW YORK CITY.
A. S. CAMERON STEAM PUMP WORKS, NEW YORK

ods such work would have involved the installation of a quantity of special machinery and the expenditure of much money to meet the difficulties which are now overcome by the use of standard commercial machines. The Cameron pump, employed so successfully in keeping the foundation excavations clear of water, does not differ from the standard pump designed for shaft-sinking purposes, and thus its adaptability for general contractors' service appears in this important piece of public work.

An Improved Hardwood Floorer

FROM time to time inquiry is made for something above the ordinary in the line of hardwood floorers. As a successful result of effort along this line there is herewith illustrated a new and improved type of machine, which, though it has only been on the market a short time, has proven a wonder to flooring manufacturers because of its excellent work, ease and quickness of adjustment and rapid feed.

The machine will work material 5 and 10 inches wide and 8 inches thick. Its frame is solidly built, open style, heavily ribbed and girded throughout. The feed is the main feature of construction. It consists of four double-geared, down-driven rolls. The two upper in-feeding rolls are carried on a pair of side housings and are raised and lowered simultaneously by hand-wheel, as shown in illustration. This arrangement insures perfect alignment. The out-feeding rolls are driven from the in-feeding end of the machine by chain and sprockets. The cut shows the spring pressure to the upper in-feeding rolls, which does away with the old system of cumbersome weights and levers.

The matcher spindles are adjustable across the machine, and may be drawn clear to the side out of the way for surfacing the full width of the cylinder. The latter are solid crucible steel forgings, four-sided and slotted. Upper cylinder bearings are rigidly yoked together and raise and lower on large, square-headed screws mounted on ball-bearings. The lower cylinder is adjustable for alignment, and with bar after-cut draws out at side of machine for convenience in setting and sharpening the knives.

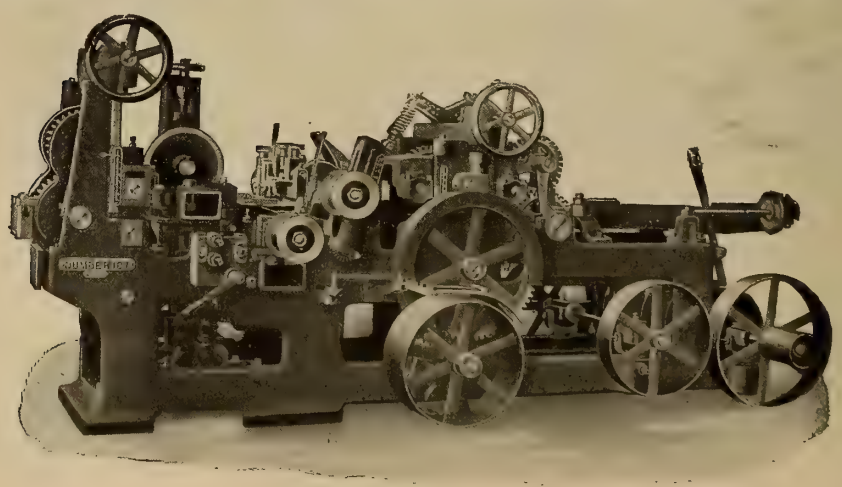
The machine is equipped with patent roller hold-downs, which insure a perfectly fitting tongue and groove. The use of stud gears has been eliminated, and all bearings are self-oiling.

For further information regarding this machine, address the manufacturers, J. A. Fay & Egan Company, 226-246 W. Front street, Cincinnati, Ohio.

Bell Ringing Transformer

A NEW transformer has been put on the market by the Westinghouse Electric & Manufacturing Company which will permit the use of the regular lighting current in ringing a door bell.

The advent of the bell-ringing transformer marks another wonder-



NO. 197. SPECIAL HARDWOOD FLOORER OF J. A. FAY & EGAN CO., CINCINNATI

WESTINGHOUSE BELL-RINGING TRANSFORMER

ful stride in the application of electricity to modern life. It relieves another care at a very small expense; it will displace five or six ordinary house batteries and last a lifetime. The operating cost is almost *nil*, and the first investment compares favourably with that of the house-battery system; in the end the bell-ringing transformer is much cheaper than the battery system, which requires continuous repairs.

The Philadelphia Company, of Pittsburg, Pa., has replaced all its batteries by and equipped its entire building with the Westinghouse bell-ringing transformer.

Trade Notes

The Allis-Chalmers Company, Milwaukee, Wis., reports the following recent sales: Mershon - Bacon Company, Bay City, Mich., 200-kilowatt, 600-volt, 60-cycle, 3-phase, 900-R. P. M. alternator; Passaic Cotton Mills, Passaic, N. J., 18 and 28 x 36 heavy-duty, cross - compound, non-condensing engine; Fuld & Hatch Knitting Company, Cohoes, N. Y., 600-kilowatt, 3,600-R. P. M., 480-volt, 60-cycle, 3-phase condensing steam turbo generator; Virginia Electric Power & Water Company, Virginia, Minn., 375-kilowatt, low-pressure turbine connected to 2,300-volt, 60 - cycle, 3 - phase alternator; Weed Lumber Company, Weed, Cal., 750-kilowatt, 3,600-R. P. M., 60-cycle, 3-phase, 600-volt condensing steam turbine unit; Morris & Co., Oklahoma City, Okla., 280-kilowatt, 480-volt, 2-phase, 60-cycle, revolving field generator direct connected to a 16 and 32 by 36 cross-compound condensing engine at 100 R. P. M., one 350-kilowatt generator with the same characteristics and speed, direct connected to an 18 and 36 by 42 cross-compound condensing engine; Armstrong Cork Company, Camden, N. J., a gas-engine generating unit, comprising an 18 by 24 tandem horizontal double-acting engine using producer gas, 200-kilowatt, 250-volt, 200-R. P. M., direct-current generator direct connected to the engine.

For supplying the motor-driven pumps of its municipal water filtration plant the city of Cohoes, N. Y., has installed two Westinghouse gas-engine driven, direct-current generator sets, using producer gas as fuel. Both engines are of the three-cylinder type, 15 by 14 inches, and develop 125 horse-power. They are direct connected to two 75-kilowatt, 125-volt Westinghouse direct-current generators. The output of these machines furnishes power for the motors driving the pumps of the city water supply, besides several other small motors about the plant and the local lighting. The producer gas for this installation is derived from two 125 horse-power J-25 Westinghouse gas producers. The use of the gas producer in connection with the gas engine in a small plant of this kind is found to secure many advantages of economy, efficiency and ease in operation over the equivalent combination of boilers and steam engines. The large number of such gas-producer plants which have been installed in this country attest the increasing popularity of this modern type of power plant.

News Items

Mr. Walter Loring Webb, C.E., has become associated with the Roberts & Abbott Company, Inc., consulting, supervising and operating engineers, of Cleveland, Ohio, and will represent this concern in Philadelphia and vicinity, with his office at 1026-28 Real Estate Trust Building, at that city.

Dean F. E. Turneaure, of the College of Mechanics and Engineering of the University of Wisconsin, gave two addresses before the instructional staff of the College of Engineering of the University of Illinois on February 10 and 11. His subject on the first day was "The Stress in Bridges Under the Load of Moving Trains" and on the second day "Some Features of the Manhattan Suspension Bridge."

The Concrete Bureau has been established in Boston, Mass., for the practice of concrete engineering and for advancing concrete construction throughout New England. Rolf R. Newman, engineer and manager, a graduate of the Massachusetts Institute of Technology, leaves a position as assistant engineer in the concrete department of French & Hubbard, of Boston, to take up his new work with the Concrete Bureau. His experience has included concrete construction work under E. L. Ransome, of New York, concrete construction in California as assistant and resident engineer with the Kern River Company, and with the San Joaquin Light & Power Company, of Los Angeles. The Concrete Bureau, whose aim it is to make the advantages of concrete better known and to develop concrete construction in New England, hopes to receive the hearty co-operation of every concrete engineer, architect and contractor in the New England field in the effort of broadening the field of the usefulness of concrete in New England and to get the best possible results out of its application.

The contract for the construction of the power development on the Etowah River near Creighton, Ga., for the Blue Ridge Power Company has been secured by Frank B. Gilbreth, Inc., No. 60 Broadway, New York. This work will include the construction of a Ransom hollow dam 42 feet high and 600 feet long, and a reinforced concrete power house sufficient for 4,000 horse-power.

The world's record for rapid sales of automobiles to individual buyers was established at the ninth annual Chicago Show, when Thomas B. Jeffery & Co., makers of the Rambler, sold 175 separate cars in seven days, making a total of $350,000 worth of automobiles. The demand was not for the low-priced car, as many had anticipated, but the buyers seemed to desire power, comfort and quality more than cheapness. The average price of the cars attaining the largest sales was $2,000.

We regret to note the death of Mr. Charles F. Aaron, ex-president of the American Supply and Machinery Manufacturers' Association, who passed suddenly away at his home in Plainfield, N. J., late on March 4.

The manufacturer is always looking out for some improvement in the production and utilization of power. For this reason the tubular boiler has superseded the plain water-boiling tank, and the watertube boiler is a later addition, the object being more rapid steam production and more economic coal consumption. Besides, draft regulating apparatus are now used, which were introduced as supplements, and developed to substitutes, for chimneys. Generally, fans are used for producing mechanical draft, for the following reasons: first cost, economic operation, increased efficiency in steam, and some other features, which are dealt with in a book entitled "Mechanical Draft," published by the Buffalo Forge Company, Buffalo, N. Y.

THE LATEST CATALOGUES

In writing for Catalogues, please mention Cassier's Magazine

Locomotives

American Locomotive Company, New York. Bulletin No. 1,000 of this concern is devoted to the description of Mallet articulated compound locomotives for freight haulage, all of the engines described being fired with various grades of coal.

Dryers

Ruggles-Coles Engineering Company, New York. This firm has just issued its new catalogue, covering drying apparatus for road-making, ceramic and pigment raw materials, organic and inorganic substances. Each type of dryer is described and illustrated, as are some apparatus in installation. Letters received from users of Ruggles dryers, and a voluminous list of such people close the booklet.

High-Speed Trucks

J. G. Brill Company, Philadelphia, Pa. Catalogue No. 187 contains a detailed description of the "27-M. C. B. Truck" made by this concern. Several handsome pictures illustrate the truck and its making and, beside the text, all the necessary information may be gathered from the diagrams added to this booklet.

Recording Pressure Gauges

Bristol Company, Waterbury, Conn. Bulletin No. 114 describes gauges for pressure, water and vacuum, with 6, 8 and 12-inch dials, for stationary, portable and switchboard service, covering all commercial ranges of pressure and vacuum. A number of chart sections are reproduced.

Electric Lamps

National Electric Lamp Association, Cleveland, Ohio. Bulletin No. 6G deals with tungsten street series lamps consuming from 1 to 1.25 watts per C. P. It describes the operation and regulation of these lamps, and tables and curves give an idea of their light distribution and efficiency.

Blowing Appliances

Buffalo Forge Company, Buffalo, N. Y. Catalogue No. 178, edition 1910, of this company, is a stately book of 300 pages, devoted to the description of blacksmiths' requirements. All the appliances of the smithing industries are described, illustrated, and their prices given. Among the products of the company are: portable down-draft and electric forges, the Crane combination woodworker, pressure, volume and steel-plate blowers, exhausters, armour-plate punches and shears; also, heating, ventilating and drying apparatus, centrifugal pumps, fans, etc.

Steam Meters

Sargent Steam Meter Company, Chicago, Ill. "Instruments of Precision" is the title of an attractive booklet dealing with the gas calorimeters made by the above firm, which are described in detail. The apparatus is intended for determining the calorific value, dust, tar and moisture contents, in commercial and inflammable gases. A price list, giving the cost of the apparatus as well as of its parts, is also found in this publication.

Mine Locomotives

Jeffrey Manufacturing Company, Columbus, Ohio. Bulletin No. 17 treats of electric mine locomotives, a number of which are illustrated. The book takes up, also, locomotive motors, induction coils, resistance coils and controllers, and finally deals with electrically-equipped yard trucks, electric generators, and various coal cutters.

Transmission Rope

THE use of rope for the transmission of power between rotating shafts is now so well established that it is accepted as one of the standard methods, to be used when, in the judgment of the engineer, the conditions indicate its special availability. Rope transmission has thus become a department of engineering work, and in many large manufacturing establishments most effective installations of this mode of conveying power may be seen.

To the uninitiated the principal problems included in the use of rope for the transmission of power may appear to be those involved in the location of the shafts, the speeds and directions of motion, and the obstacles and mechanical difficulties to be overcome. These doubtless all have their weight. Rope transmission may be used in the delivery of power between shafts situated at right angles as to render the use of belt very undesirable, especially when large amounts of power are involved. In like manner the distance between shafts is an important factor, rope driving being adapted for distances either greater or smaller than can be employed with belting. All these elements go to make up the successful transmission when they are skillfully handled, and unless they are given proper attention from experienced engineers the best efficiency cannot be expected.

Apart from the kinematic problems involved in the use of rope for transmission of power, there are other essentials which go to make up the successful transmission. The design and construction of the sheaves over which the ropes are run, including the correct angle for the grooves, the best methods for attachment and the attainment of correct balance, all go to make up the success of an installation.

In addition to the general lay-out of a transmission system, probably the rope itself forms the most important factor. Strength, uniformity, elasticity and durability are all essentials, and to these must be added such reasonable cost as will make its use efficient from the commercial viewpoint. The ill-advised use of ordinary rope, wholly unsuited for transmission purposes, has had much to do with adverse opinions sometimes expressed concerning rope transmission.

The determination of the best fibre for use in manufacturing transmission rope demands not only mechanical tests, but also physical examination, including the employment of the microscope, both in the original selection and in the subsequent maintenance of the approved standard of quality. The material being thus selected, there follows the necessary care in the twist of the threads and the lay of the strands.

The continuous and rapid bending and straightening of a transmission rope in its passage over the sheaves naturally causes an internal movement among the fibres, an action which tends to produce wear and disintegration if a proper lubricant is not introduced throughout the entire structure. This most important feature has much to do with both the life and the efficiency of a rope, since internal friction both absorbs work and weakens the fibres. When such care is taken, both as to material and to details of manufacture, a rope transmission may be so designed and installed that satisfactory performance, long life and high efficiency are assured.

When it is realized that a large proportion of the power generated by the boilers and engines of a manufacturing plant is absorbed in transmission, the wisdom of procuring the best becomes self-evident.

So far as fibre is concerned, it is well known that suitable material can be selected from the Manila hemp. As a lubricant, plumbago has been demonstrated to serve here, as elsewhere, to reduce friction to a minimum. In manufacture, nothing can replace care, experience and continual inspection and supervision.

"STEVEDORE" Transmission Rope

Hunt's Patent Plumbago Laid, made four strand with heart

A THOROUGHLY lubricated Manila Transmission Rope of selected fibre, for both indoor and outdoor use.

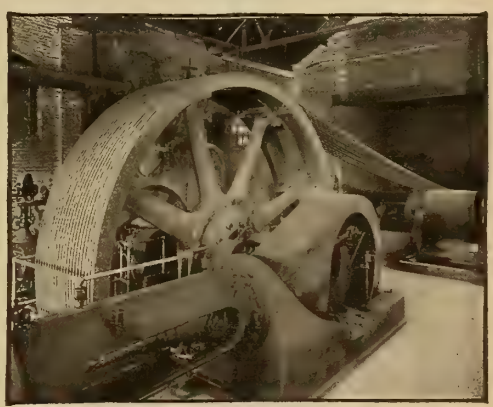
The only rope on the market which combines all the essentials of a real transmission Rope. It is thoroughly and uniformly lubricated, has an even grade of long fibre throughout, and has the twist of the threads and the lay of the strands exactly suited to the work to be done.

No. 0823.
OUTDOOR ROPE DRIVE BETWEEN BUILDINGS, EQUIPPED WITH 3,000 FT. OF "STEVEDORE" ROPE IN ONE BAND, DISTANCE BETWEEN CENTERS OF SHEAVES 165 FEET.

The Results?

Added Life.
Added Efficiency.
And although the first cost is slightly higher, a saving of money in the end.

We guarantee that more work can be done with it, in proportion to its cost, than with any other rope in the market, without any exception whatever, and will gladly refund the difference in price if it is not all we claim. You cannot lose one cent in making a trial of this rope.



No. 0840.
MAIN DRIVE EQUIPPED WITH TWENTY 1¾-INCH "STEVEDORE" ROPES.

The standard size "coil" kept in stock contains about 1,200 feet of rope, but we make them of any size, up to several thousand feet each, in one piece, with out a splice.

"Manila Rope" a treatise on Rope Driving by C. W. HUNT, mailed upon request.

C. W. HUNT COMPANY

(ESTABLISHED 1872)

WEST NEW BRIGHTON, NEW YORK

New York Office: 45 Broadway

Water-Softening Appliances

IN most parts of the United States "hard water" is well known as the only kind of water directly available. The householder has to struggle with this inconvenient substitute for pure water as best may be; but the engineer regards it as the bane of his existence, causing his boilers to be coated with scale, increasing his coal bills, reducing the capacity of his power plant, and shortening the life of his equipment.

A steam boiler is, primarily, a device for generating steam by the application of heat to water. If there was nothing but pure water delivered into the boiler the conversion of its contents from the liquid to the gaseous state would leave the interior of the generator in the same condition in which it was originally made. If, however, as is usually the case, the liquid introduced into the boiler contains solid matter in suspension and various salts in solution, these substances, not being evaporated by heat, will be left behind, and thus will accumulate to cause trouble and ultimate disaster.

Various methods have been devised to remove the accumulations of sediment and coatings of scale from the interior of boilers which are fed with impure water. Some are fairly effective, while others are utterly worthless, but all of them are based upon the defective principle of endeavoring to take out of the boiler things which should never have been permitted to get into it.

Water which is called "hard" has in solution certain salts of calcium and magnesium, especially their carbonates and sulphates. These are thrown down by the action of heat, and thus cause the formation of hard and adherent scale upon the interior surfaces of the boiler, depriving it of the protection of the water and impeding the transfer of heat. When, in addition, the water contains clay or mud in suspension, this solid matter is gradually permitted to settle and become baked upon the boiler sheets, thus combining with the scale to make trouble. Both mud and scale are notable examples of the inconveniences due to matter in the wrong place, and the obvious remedy is to put them somewhere else.

We thus come to the positive rule that the proper way to keep a boiler clean is to put only clean water into it. If the water contains mud which will settle in the boiler, give it a chance to settle somewhere else. If it contains carbonates, which are precipitated by temperatures which exist in the boiler, the right thing to be done is to raise the temperature of the water to the precipitation point in advance and let the separation be done outside of the boiler. If the water contains sulphates, forming hard scales in the boiler, the reasonable treatment is to add to the water sufficient lime and soda to convert these constituents into carbonates, so that they may be got rid of with the rest.

Mud, clay, and other materials, which are simply held in mechanical suspension, may readily be separated by furnishing time and opportunity for subsidence, thus enabling them to be blown off outside the boiler.

All these facts are well known; but like many other facts, they are utilized only by people who understand the importance and value of employing them. The competent power-plant engineer, however, realizes that an essential portion of his equipment is an effective water-softening and purifying equipment, while the railway superintendent of motive power installs at every watering station an outfit which will insure the supply of pure water to his locomotives and minimize the delays and losses otherwise caused by burnt sheets and tubes and diminishing steaming power of his engines.

Any boiler which becomes choked with mud and coated with scale is a positive witness to the neglect with which it has been treated, a neglect which is all the more reprehensible because it is so wholly unnecessary.

DODGE

AN APPARATUS THAT WILL SAVE FUEL, SAVE YOUR BOILERS AND SAVE WORK

The Eureka Water Softener and Purifier installed in your plant will provide your boilers with pure, soft feed water.

Preventing the formation of scale, thus keeping the boiler tubes clean so they will not pit or corrode, and greatly prolonging the life of the boilers.

IT WILL TAKE LESS FUEL AND HEAT TO TURN WATER INTO STEAM, when the heat does not have to penetrate a thick coating of scale.

And there will be no need of cleaning the boilers out by hard and disagreeable labor.

THE "EUREKA" WATER SOFTENER AND PURIFIER

treats and purifies the raw water before it enters the boilers, eliminating from it all scale-forming matter. This does away with the use of expensive "dope" and gradually removes all scale that may be in the boilers when the "Eureka" is first installed.

That's what this machine is doing at many of the best power plants in the country.

Doing it automatically, with almost no attendance and only about a half-hour's attention each day.

And at practically no cost, because the saving made by the "Eureka" has much more than offset all the expense connected with it.

If you will send us a sample of the boiler feed water you are now using, we will analyze it and tell you just what the "Eureka" machine will do for you, what the cost will be, and how long it will take the apparatus to pay for itself.

Or let us send you our Bulletin C-117, "The Water Question." It tells all about the "Eureka" Water Softener and Purifier,—how it operates and what it does. Please fill out the coupon and return it to us at once for a copy of this book.

DODGE MFG. CO., Sta. C-11, Mishawaka, Indiana.

Send Your Bulletin C 117, "The Water Question"

Name.....

Firm.....

Position.....

Town.....

State .....

DODGE MANUFACTURING CO.

Sta. B-11 Mishawaka, Indiana

The Sustaining Power

IN handling materials there are various things which have to be done. Sometimes a heavy burden has to be raised; then it may have to be transported; while, again, it may be necessary to lower it, carefully, precisely and deliberately. With the older contrivances, such as the lever or the rope tackle block, it was possible for a man to make a powerful effort for a short interval of time and lift a heavy weight through a moderate distance; but when it was necessary to hold the burden at a given point there was demanded a power of endurance altogether different in character and far more exhausting in its nature.

When the differential chain block came into use, thanks to the inventive genius of Weston and the manufacturing capacity of the Yale & Towne Manufacturing Company, the mechanical world was provided with an appliance which, much to the surprise of the uninitiated, would hold the load sustained at any point without effort on the part of the operator. The convenience of this feature obscured for a long time the fact that the power which sustained the load lay in a frictional resistance inherent in the apparatus, a resistance which was necessarily greater than the load itself, and which had to be overcome by the operator whenever he did any hoisting. The method was similar to that which might be supposed to exist if a driver checked the speed of a vehicle by applying the brake while at the same time urging the horses forward with whip and voice.

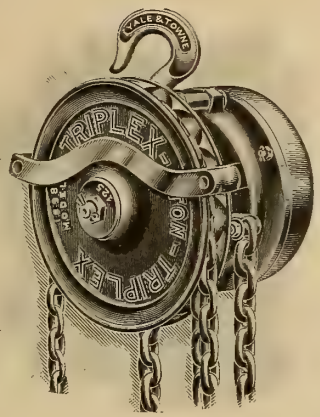
Nevertheless, the advantage of the sustaining power was so great that the fact of the moderate efficiency, due to the frictional resistance, was accepted without objection, until the same inventor, the late Thomas A. Weston, produced a hoist in which the frictional resistance, upon which the sustaining power depended, opposed no resistance to the hoisting effort. This desirable end was attained by separating the hoisting and sustaining mechanisms so that the sustaining power comes into action only when the operation of hoisting ceases, thus relieving the operator of one-half of his burden.

In most modern appliances for handling materials the operation of hoisting is but one portion of the work. The chain block now forms a portion of the overhead traveler, or of the crane, and it must hold its load sustained during the operation of travel from one point to another. It must sustain its load just where it is left when the operation of hoisting ceases and keep it where it has been left until the hand of the operator pulls upon the chain either to hoist or lower.

Now that this sustaining power, due to properly controlled friction, is separated from the mechanism by which the hoisting is effected, the efficiency of the hoist is raised from about 30 per cent. to nearly 80 per cent., a result which, had it been effected with the steam engine of the internal-combustion motor, would have attracted interested attention throughout the entire scientific world. As it is, the scope of the chain hoist has been so widely extended that it has replaced power hoists in many combinations, and thus a quiet transformation has been effected which is none the less important because it has been inconspicuous.

The manner in which the effect of friction has thus been controlled to furnish aid when required without offering resistance to the useful effort is an excellent example of the application of the skill of the engineer to a simple machine, making a helpful friend out of a former antagonist while increasing efficiency and economizing power.

As in the case of all properly designed and installed mechanical appliances, the chain hoist thus acts to conserve human energy, a natural resouce too often uselessly and inefficiently employed in operations better performed by machinery.



FRICTION

CHAIN Blocks always used to depend on a certain amount of **friction** to prevent their dropping their load. That friction had to be overcome in the **lifting**—which meant a harder pull for the man on the chain and increased wear on all parts.

The Triplex Block raises and lowers by separate mechanisms. No extra friction to be overcome—the pull on the chain all goes to lifting.

Which is **why** the Triplex Block does about twice the work of any earlier device.

No miracle about it at all.

And it **is** so well made.

The old-fashioned Chain Blocks have their uses still; and they cost less. Even those we make, which wouldn't cost less and be as safe.

4 styles: Differential, Duplex, Triplex, Electric.
42 sizes: One-Eighth of a ton to forty.
300 active stocks: ready for instant call all over the United States.

The Book of Hoists tells much—Yours for a Postcard

The Yale & Towne Mfg. Co.

Only Makers of Genuine *Yale Locks*

9 Murray Street, New York

Foreign Warehouses: The Fairbanks Co., London and Glasgow. Fenwick Freres & Co., Paris, Brussels, Liege and Turin. Yale & Towne Co., Ltd., Hamburg. F. W. Horne, Yokohama
Canadian Warehouses: The Canadian Fairbanks Co., Ltd., Montreal, Toronto, St. John, N. B., Winnipeg, Calgary, Vancouver

Respect the Rock Drill

IF we were to ask one only casually acquainted with the rock drill to tell us what it is and what it does, we would, perhaps, learn from him that it is one of the simplest machines, its sole function being to reciprocate a piston with considerable rapidity, the piston carrying a steel bit which, by constant, forcible striking of the rock, gradually crumbles its way into it, forming a hole of any required depth. This would not be an untruthful statement, but it would be an absurdly inadequate one. The simple fact is that there are few accepted inventions which so completely satisfy so many exacting conditions as does the rock drill.

The drill, in a way, does rough work, rough surroundings are its habitat, and it is handled and operated by men who would also, perhaps unthinkingly, be characterized as rough. It must, therefore, in itself be rough and strong exteriorly, so that it can stand the most strenuous use and unlimited abuse. It must be able to put in holes in the rock in any direction, vertically downward or vertically upward, or at any angle between, and in any vertical plane all around the circle. It must be set in the required position quickly and precisely, and while drilling each individual hole it must be held accurately and securely, yet never rigidly, in position and direction, and provision must be made to constantly feed forward the drill as the steel advances into the rock and to withdraw it for changing bits or for starting another hole.

Perhaps the most important and responsible detail of the drill is its valve and valve motion. There can be no positive valve motion, as with a steam engine, for the double reason that the stroke of the piston in the drill cylinder constantly varies, and if an otherwise satisfying mechanical movement and connections could be devised the mechanism would be soon demoralized by the jar of the machine; and yet the valve must, and does, admit the air or steam freely, so that the piston moves with the required force, the piston must normally avoid striking the cylinder heads, and whatever the position of the drill, or of the piston in the drill, it must always and instantly obey the throttle.

The drill bits, of course, wear in use, and in hard or gritty rock the wear may be rapid, so that it must always be possible to change a steel for another. The chuck must, therefore, hold the bit securely under the shock of the repeated blows, and yet it must be tightened or loosened without delay. This constant changing of bits, and the minute movements of the shank in the chuck under the repeated blows, of course entails wear, which must be provided for, so that the rectilinear truth of the successive bits, when inserted, may be relied on.

Constantly, while the steel is advancing into the rock, it must be kept in rotation, the turning of piston and steel not having any regularity of angular movement, but still insuring that the cutting edges of the bit shall each time strike in a different place. The automatic rotation provided, while it insists upon the turning of the piston and bit more or less at each stroke, still does it in a yielding way, so that accidents or breakages do not occur if at any time the bit refuses to be immediately turned as much as the rotation device would normally require.

The rock drill lives the strenuous life. It is subject to severe wear and frequent accident, so that its parts are liable to require renewal at any time. Every part of every standard drill is made so accurately to gauges that stocks of such parts are maintained wherever the drills may be in every part of the world, and they interchange with and replace each other as though there was but one machine of its size and type in existence.

Manufacturing News

A New Use for the Lifting Magnet

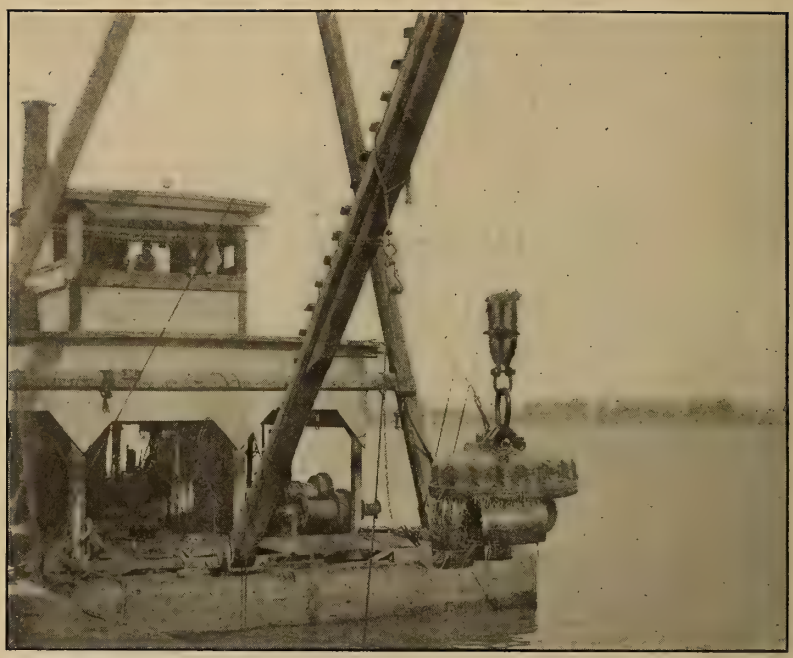
THE lifting magnet has now been employed for several years in and about iron works and manufacturing establishments in connection with cranes and hoisting machinery, because of the convenient manner in which it enables masses of iron, such as rails, pig iron, etc., to be picked up and released at the will of the operator who controls the crane.

Recently, however, a new application of this method has been made, which is both interesting and instructive, and shows how modern methods permit the accomplishment of feats which would formerly have been considered impossible.

A few months ago a barge, which was laden with 1,500 tons of wire nails in kegs, besides steel barrel-hoops, staples and barbed wire, had been towed from Pittsburg to New Orleans, and while endeavoring to make a landing at the latter city the barge broke loose from the tug which was handling it and sunk in 55 feet of water. The work of salving the valuable cargo was immediately begun by expert divers, and a portion of the material was recovered. It was found, however, that the barge had broken in two, and that a part of it had been carried out about 150 feet from shore, and lay at a depth of about 100 feet, at a point where the swiftness of the current rendered work with ordinary diving apparatus impracticable.

Although the lifting magnet had not hitherto been used for submarine operations, it was determined to make the trial of the apparatus for this novel undertaking, and a magnet made by the Cutler-Hammer Clutch Company, of Milwaukee, was sent to the scene by the Carnegie Steel Company, for use by the American Steel & Wire Company, by whom the sunken cargo was largely owned.

The experiment was crowned with success, and a great part of the sunken quantity of iron and steel has been raised to the surface by this novel method. The magnet is lowered into the water until it reaches the material, when the electric current is turned on; the masses of steel are attracted and held so securely that they can be hoisted to the surface and delivered to the dock without the aid of any human intervention other than the control of the current by the operator on



RECOVERING KEGS OF NAILS BY USE OF THE LIFTING MAGNET. THE CUTLER-HAMMER CLUTCH COMPANY, MILWAUKEE

the crane. When the load is swung around to the dock the current is reversed and the magnet releases its hold, the burden is dropped, and the apparatus is ready for another trip.

The capacity of the apparatus will be understood when it is stated that it has lifted five kegs of nails, weighing 100 pounds each, besides a bundle of hoops, weighing 70 pounds, and a bundle of fence-wire of 155 pounds, a total of more than 700 pounds, while loads of four kegs of nails have been frequent. In some instances the kegs in which the nails were contained were broken in the operation of lifting, but the contents adhered to the magnet in the original shape of the kegs, the whole mass being held together by the magnetism.

The principal difficulty involved in the use of the lifting magnet beneath the surface of the water naturally lies in the maintenance of the insulation in the presence of the moisture. The pressure of water at a depth of 100 feet corresponds to more than forty pounds per square inch, and it was necessary to devise some method of preventing this pressure from forcing through the insulation. The magnet used by the Cutler-Hammer Clutch Company was especially prepared for this service by the exhaustion of the air around the coils, followed up by the delivery of the insulating solution under a pressure of 150 pounds, this solution being applied warm and solidifying upon cooling. The wires through which the current was supplied were thoroughly insulated, and also protected by rubber hose. Special line wires were run to the dock for the supply of current, this being supplied at a pressure of 110 volts, the magnet requiring 53 amperes during operation.

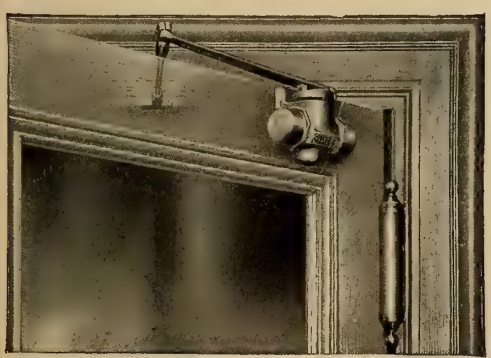
The material raised was naturally rusted by reason of its immersion in the river, but treatment in the tumbling barrel, with sawdust and soda, restored the original brightness, and made it available for use.

Yale Double-Acting Door Check

IN a novel and attractive little booklet the Yale & Towne Manufacturing Company, of New York and Stamford, describes and illustrates an article which has long been needed. The new check does for double-acting doors what the Blount door check, which is made by this

CHECK ON DOOR OPENED IN

same company, has long done for single doors: it closes them quickly, firmly, and without that flip, flop, flapping so disagreeable and dangerous to all using double-acting doors. The check consists of a short vertical cylinder, through the top of



CHECK ON DOOR OPENED OUT

which projects the spindle, to which is attached the main arm. To the outer end of the latter is attached the adjusting arm, the other end of which is fastened to the door jamb, so that as the door moves the spindle is caused to rotate.

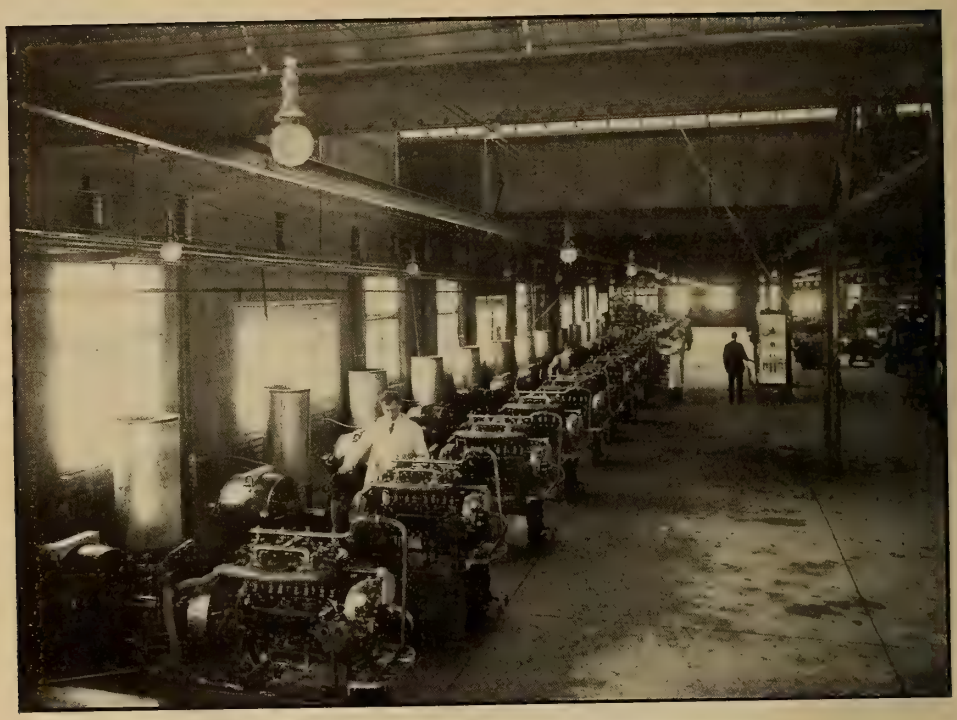
By an ingenious construction of the main arm bracket the door is free to swing in both directions, the arms dropping below the soffit of the door frame when the door swings to the side opposite to that on which the door check is attached, and passing over the top of the door when the latter is moved in the contrary direction.

The horizontal transverse cylinder at the bottom contains the liquid chamber, the piston and the regulating valves by which the action of the door may be controlled independently in each direction, according to the varying conditions of wind pressure. The non-freezing liquid is hermetically sealed within the liquid chamber, and a third regulating valve controls the resistance of the door to motion in either direction from its closed position.

The device is simple, compact, pleasing in design, and as absolutely reliable in service as the Blount door check.

The new steel car works of the Pullman Company, at Pullman, Ill., will be supplied with light and power by two 1,000-kilowatt Westinghouse high-pressure steam turbines. The steam elements of these units will operate at 150 pounds pressure, exhausting into a vacuum of 28 inches, maintained by Westinghouse-Leblanc condensers. The principal service rendered by the new equipment will be the generation of power for the manufacture of steel cars, which is to be carried on upon a large scale in the new plant of the Pullman Company.

The American Locomotive Company of New York have just published a booklet containing tables of the tractive power of simple locomotives. There are compiled in this bulletin eight tables of the power of locomotives, ranging in boiler pressure from 100 to 220 pounds per square inch, and a number of tables of cylinder volumes, internal tube areas, tube heating surface, etc.



MOTOR TESTING DEPARTMENT AT THE RAMBLER AUTOMOBILE WORKS

Testing of Automobile Engines

IN constructing a thoroughly reliable automobile engine it is essential for the builders to maintain a first-class testing department devoted exclusively to the work of examining the engines to be put on the market. In the following we give a description of the testing department of the Rambler factory of Thomas B. Jefferey & Co., which occupies one entire building, covering floor space equivalent to one-half the floor area of the original Rambler factory.

Seventeen dynamos are here arranged on seventeen concrete stands, each stand making a complete unit, with necessary cooling apparatus and means to carry off the exhaust gases.

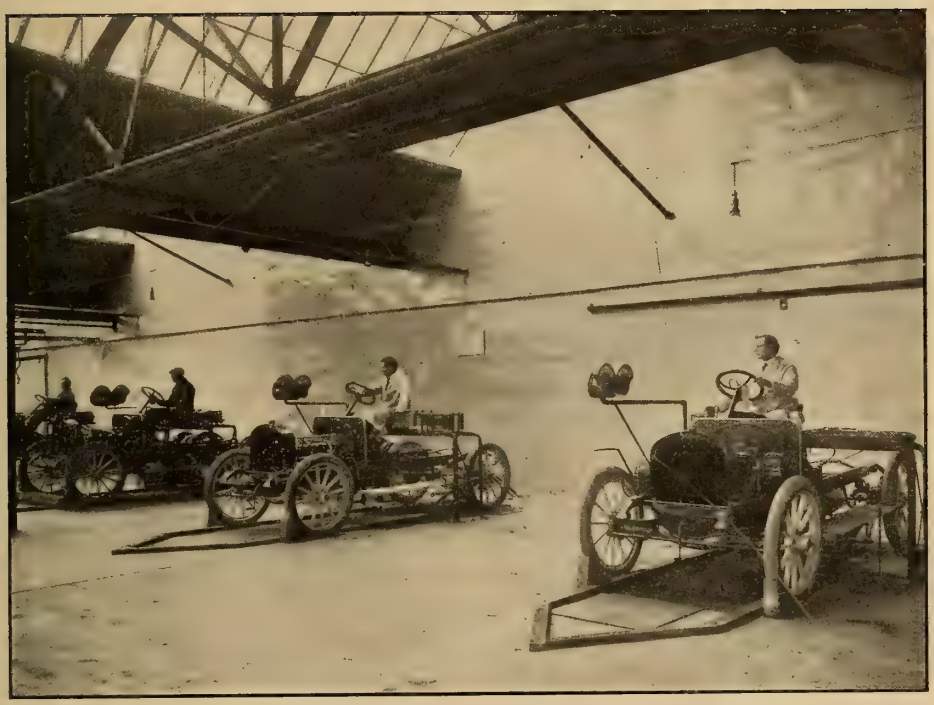
When a motor is completed in the engine assembly department, it is picked up on a traveling crane, carried to the testing department, and located on one of these testing stands, where it is first limbered up and then tested to establish its horse-power rating, and to detect its most insignificant faults before it is placed in the car.

First, the dynamo turns the engine while the new parts are being thoroughly limbered preparatory to running the engine under its own power. Then the operation is reversed. The engine is started and it drives the dynamo. This operation continues for many hours, until the engine is thoroughly worked in and scientific tests show that it is delivering its rated horse-power.

Every engine is closely watched during this process, and if trouble of any kind, such as a knocking bearing, noisy gears or valves, becomes apparent, the difficulty is immediately remedied. Before it leaves this stand the engine must run without vibration and without noise.

These seventeen stands are constantly busy, while, in addition, there is one reserve stand for experimental purposes.

After an engine is assembled in the



REAR-WHEEL TESTING OF RAMBLER AUTOMOBILES

chassis, it is returned to this department and a rear-wheel test is taken. The car is securely clamped on two immense rollers, from which a dynamo is driven by means of a chain. The power delivered is determined from an indicator connected to the dynamo. This test detects any possible error in assembly, any difficulty in transmission or axle, and assures uniform results at the rear wheels.

Such exacting manufacturing requirements are responsible for the superiority of the Rambler.

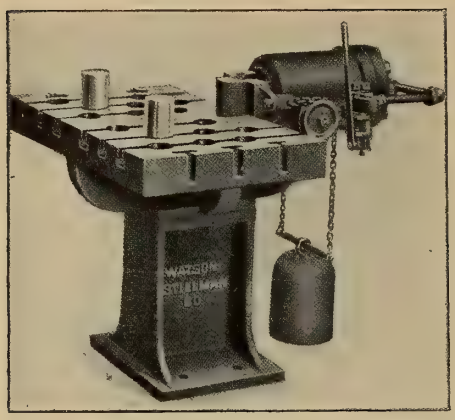
The Davis-Bournonville Company is extending the scope of its work in the development of the oxy-acetylene welding and cutting process, and announces that the Ohio Welding & Manufacturing Company, of 828 West Sixth street, Cincinnati, Ohio, will act as dealer. A large demonstrating plant has been installed, including not only the welding equipment, but also an oxygen plant, enabling all classes of repair work adapted to the oxy-acetylene process to be executed. The Davis-Bournonville Company will also open a demonstrating and repair shop very shortly at 2121 East Second street, S. E., Cleveland, Ohio.

A Correction

We desire to correct some errors which appeared in connection with illustrations in the article by Mr. Emerson on Railway Fuel Supply, in the March issue of this magazine.

The Coaling Station built by Fairbanks-Morse & Co., illustrated on page 620, serves four tracks, not three as stated, and its capacity is 4,000 tons instead of 400 tons.

The Concrete Coaling Station, on page 624, was built, not by Messrs. Roberts & Schaefer, but by Fairbanks-Morse & Co., of Chicago, while the station shown on page 621, and built by Roberts & Schaefer, is at Ridgely, Ill., and not at Asheville, N. C., as stated in the title.



HYDRAULIC BENDING MACHINE. WATSON-STILLMAN COMPANY, NEW YORK

Hydraulic Bending Machine

THE Watson-Stillman Company, of New York, has just introduced two new bending machines which should prove of interest to all who have large pipe, structural sections, automatic parts, and similar pieces to bend.

The frames and cylinders of these machines are cast iron, and the cylinders are copper-lined. The rams and bending pins are made of machinery steel. A positive stop is provided in both instances to prevent the ram from passing out beyond a safe limit.

Owing to limitation of space, only the larger one of the two machines is here illustrated. This is capable of exerting 30 tons pressure. The table is 4 feet wide by 6 feet long, and has two opposed 7-inch cylinders of 12 inches stroke arranged to operate in either direction, the double-headed ram extending between them.

The table, as shown, has twenty-one holes on each side of the ram and staggered in six rows. The movable pins are interchangeable and 4½ inches in diameter. The larger or bending pin shown in the centre is attached to a saddle on the ham. The ram works in machined guides, and is covered to prevent scale or dirt from reaching the contact surfaces. These surfaces are further protected from dirt by plugging the oil holes in the cover with screw plugs.

The cylinder heads are removable and provided with air passages, which also permit drainage. The valves are placed in one body, and may be operated by any of the four levers at the corners of the press. The arrangement is automatic, so that opening of pressure or release valves for one cylinder opens the opposite valve of the other cylinder, the movement being stopped by removing the hands from the lever.

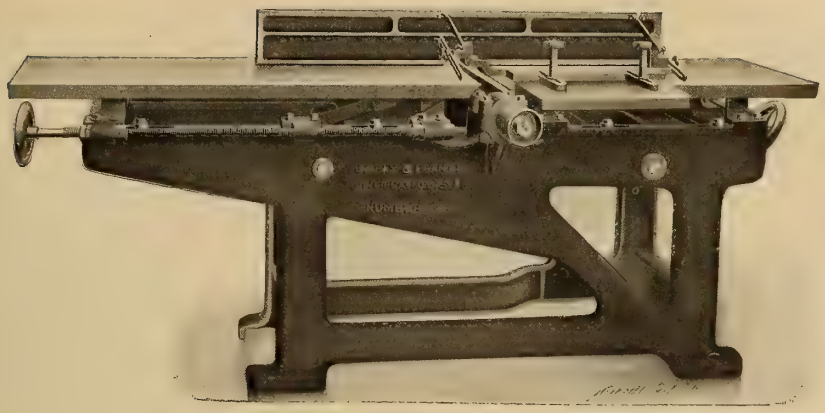
A pair of bending blocks faced with a hard steel may be substituted for the bending pin. The cylinders are cast higher up for uses where it is desirable to obtain greater power.

Belts and Their Dressing

A LITTLE while back, the John Dixon Crucible Company, for the first time in eighteen years, took up a belt in one of its mill rooms.

For eighteen years about thirty belts in that room have been run continuously; the belts are about 25 feet in length and 6 inches in width. There is a great deal of graphite dust in the room, yet these belts have run satisfactorily, without breakage or without being taken up, for eighteen years.

The belts are regularly treated with Dixon's traction belt dressing, which comes in paste form. There are many who prefer to use a solid dressing. If a quick, convenient dressing is desired, Dixon's solid belt dressing is suggested. The Dixon Company frankly state that no solid dressing equals their traction belt dressing, for the reason that some of the ingredients in their traction dressing cannot be reduced to solid form. But if the solid dressing is preferred, one may use Dixon's solid belt dressing with all safety. It is a quick, sure cure for slipping belts, but has no detrimental effect upon the belting. In any case, the use of a dressing, either paste or solid, is recommended.



FAY & EGAN COMPANY'S NO. 195 HAND PLANER AND JOINTER

Hand Planer and Jointer

THE machine illustrated herewith is designed for all classes of work done on a hand planer; it accomplishes perfectly such work as planing straight or out of wind, cornering, chamfering, beading, grooving, rabbeting, gaining and making plane, convex and concave glue joints, and has capacity for material in three sizes—20-inch, 24-inch and 30-inch widths.

The frame is substantial and well proportioned, cast in one piece, the journal bearings being embodied in this casting. Cylinder is made from a solid steel forging, and is slotted on four sides to permit the use of various kinds of knives. The manufacturers furnish their new safety circular cutter-head on this machine when so ordered.

The tables are planed and perfectly finished, giving a large, true surface to properly guide material being worked. They are each vertically adjustable on four inclines, each of which has an independent adjustment for aligning the tables. The ratchet lever is also provided, whereby both tables can be quickly drawn away from the head, giving an opening of 7 inches. An extending arm is attached to the front table to support material being rabbeted.

A fence can be adjusted to any point across the width of the table and set to any angle from vertical to 45 degrees and securely locked in such a position.

When so ordered, the machine is furnished with an attachment for angling the front table to give the desired draft on pattern work. This feature is shown in the illustration.

For further particulars you are requested to write the manufacturers, J. A. Fay & Egan Company, 226-246 West Front street, Cincinnati, Ohio, who make a standard line in woodworking machinery.

Personal

Mr. Harry G. Glass has accepted a position in the industrial and power sales department of the Westinghouse Electric & Manufacturing Company. His time will be devoted to the promotion of the co-operation between the central station and the manufacturer in building up day-loads. His long experience in the central station field and his wide acquaintance with the requirements of the central station will fit him for his new duties.

Mr. Glass began his career as engineer and local troubleman for the Waynesburg Electric Light, Heat & Power Company, Waynesburg, Pa., and he has since served with several companies in order to become familiar with all phases of the central station business.

THE LATEST CATALOGUES

In writing for Catalogues, please mention Cassier's Magazine

Oil and Gas Appliances

W. S. Rockwell Company, New York. Catalogue No. 3 of this concern explains the advantages of oil and gas over coal firing, and describes many oil-firing appliances, among which are burners for high and low-pressure oil, burner plates, pressure blowers, oil-pumping systems, pressure tanks, fire tiles, etc. All these apparatus are illustrated; besides, the booklet contains several valuable tables relating to fuel values, etc.

Combination Furnace

George J. Hagan, Pittsburg, Pa. The catalogue dealing with the Bailey combination furnace takes up in detail all the features of this furnace uniting the under-feed stoker arrangement with a sheet and pair heating furnace. Construction, consumption, etc., of the furnace are described, all necessary details considered, and a list of enthusiastic users of the Bailey furnace included in the booklet.

Gas Power Plants

Snow Steam Pump Works, Buffalo, N. Y., and Power & Mining Machinery Company, Milwaukee, Wis. In their Catalogue No. 104 these two concerns have published a beautifully finished book full of interesting illustrations of the application of gas power to various industries, manufacturing enterprises, railways, etc.

Water Weighers

Kennicott Water Softener Company, Chicago Heights, Ill. This concern has just published its Bulletin No. 36 treating of water-weighing apparatus, which furnishes exact records of the amount of boiler feed-water evaporated. The weigher and its operation are described in detail.

Air Meters

G. C. St. John, New York. The air indicator and recorder made by this firm measures the quantity of free air or gas flowing through it at all pressures in cubic feet per minute, a needle moving over a brass dial showing the quantity of air flowing, while a pencil moving with the needle makes a record of a paper ribbon or chart. The catalogue describes principles and operation of this apparatus in detail.

Steam Turbines

General Electric Company, Schenectady, N. Y. Bulletin No. 4,705 contains valuable and interesting information about low and mixed-pressure steam turbines, with horizontal and vertical shafts. Two cases for the low-pressure turbine are considered: in connection with condensing and with non-condensing engines. Turbine generators from 300 to 7,000 kilowatts are illustrated, and also dimension diagrams of the horizontal type given.

Motor for Presses

Triumph Electric Company, Cincinnati, Ohio. Bulletin No. 381, entitled "The Printer's Guide," contains, in a number of tables, data of power requirements of printing presses and other kindred information.

Oil Engines

De La Vergne Machine Company, New York. Handsome catalogue giving detailed descriptions and illustrations of the various engines built by this firm, viz.: the Hornsby-Acroyd horizontal engines, which are of the four-cycle type, and the vertical two-cycle engines. The catalogue contains also quite an amount of general information regarding the operation of gas engines and internal-combustion motors.

MANUFACTURING NEWS

Pumps

FORT WAYNE ENGINEERING & MANUFACTURING COMPANY, Fort Wayne, Ind. The Paul pump made by this concern is described in detail and illustrated. Price lists of the pumps and automatic float switches are also included in the book.

Electric Motors

TRIUMPH ELECTRIC COMPANY, Cincinnati, Ohio. Bulletin No. 341 published by this company describes the various types of its direct and alternating-current motors, and illustrates their connection to planing, milling, drilling, stamping, sawing and mortising machines, as well as hoists and cranes.

Transformers

FORT WAYNE ELECTRIC WORKS, Fort Wayne, Ind. Bulletin No. 1,118 of this company is devoted to a detailed description of its transformers, which are illustrated in all their details. A number of tables form a supplement to the information contained in this booklet.

Rubber Belt Conveyors

JEFFREY MANUFACTURING COMPANY, Columbus, Ohio. Booklet No. 35 takes up rubber-belt conveyors, which are described and profusely illustrated by a number of pictures showing such conveyors and their operation. A price list of all parts of these appliances is also found in the booklet.

Milling Machines

CINCINNATI MILLING MACHINE COMPANY, Cincinnati, Ohio. Splendidly finished catalogue, illustrating a complete line of milling machines for both the cone type and the high-power, single-pulley type, the latter in two styles, viz.: horizontal (plain and universal) and vertical. The high-power machines are equally well adapted for heavy and light cutting. The book contains also a few examples of rapid milling, indicating the great productive capacity of these machines.

Machine Tools

BURKE MACHINERY COMPANY, Conneaut, Ohio. The new catalogue issued by this firm contains descriptions and illustrations of milling, grinding, drilling, tapping and shaping machines, forges, etc. A code containing all the items mentioned in the booklet is also found in the catalogue.

Gas Engines

BRUCE-MACBETH COMPANY, Cleveland, Ohio. Handsomely illustrated catalogue treating on twin and four-cylinder engines, describing the functions of each part of and the applications of the whole engines, as such, for electrical and power plants. The booklet gives also a number of data relating to the work done by these engines and the economy afforded by the latter in comparison to other ways of power-production. Finally, there are cited a number of very satisfactory testimonials from users of the Bruce - Merriam - Abbott engine built by the above-named firm.

Transportation Machinery

CHAIN BELT COMPANY, Milwaukee, Wis. Catalogue No. 39 of this firm describes concrete mixers, elevators, water tanks, conveyors, etc. Size, weight and power data are given, as well as several attests from users of the machinery described in this booklet.

Mining Appliances

ALLIS - CHALMERS COMPANY, Milwaukee, Wis. Bulletin No. 1,438 describes two milling and cyanide plants equipped by this firm. General layout and design of the apparatus are given in detail, and the processes applied in these mills described in a practical manner.

Impact Screen

COLORADO IRON WORKS, Denver, Col. Pamphlet No. 9-B describes the application of impact screens for dry and wet screening. A number of setting drawings are also given in the booklet, besides data on wire cloth, etc.

Lubrication with Plumbago

IT has been said that friction is one of the great causes of inefficiency in the performance of machinery, and, for that matter, much of the inefficiency which exists in all kinds of work, including human labour, is due to friction, internal and external. For many purposes, however, friction is useful, and even essential, and it is a part of the work of the engineer to control it by minimizing it where it acts as an opposing resistance and by increasing it when it is usefully employed.

In this control of friction there has grown up an important department of engineering practice, accompanied, as is usually the case, with large commercial and industrial interests—the department of lubrication. From the early experiments of Morin, in 1831, through the various scientific tests made by individuals and manufacturers, and published in treatises, text-books and professional papers, the whole subject of lubrication has been made a matter for exhaustive study, and the influences of speed, pressure, character of surfaces, nature of lubricant, temperature, atmospheric conditions, etc., have been investigated and recorded.

Broadly, there are two kinds of lubricants, liquids and solids. In the former class the various oil lubricants are placed, while in the second there is but one which is extensively used, the natural material known as plumbago, or graphite. Graphite is extensively used in connection with oil, and some recent developments have made it possible for the finely divided solid to be held in suspension indefinitely, thus enabling a combination lubricant to be employed to much advantage.

It has generally been assumed that the principal application of lubricants is found in bearings of all kinds, with the intention of reducing the frictional resistance between the surfaces to the lowest point, and this is a very important portion of the subject. There is, however, another department in engineering work in which lubrication appears, namely, in the reduction of internal frictional resistance and consequent reduction of wear and in prolongation of useful life.

Thus, in the case of cables, either of wire rope or of manila hemp, there occurs a movement of the fibres upon each other whenever the cable is deflected from a straight line. The amount of this rubbing depends upon the radius of the sheave over which the cable is bent and upon the position of the fibres in the body of the cable, while the frictional effect depends both upon the amount of rubbing and the pressure of the fibres against each other, this latter being governed by the tension of the cable.

It will thus be seen that in the use of rope transmission the efficiency, so far as the internal resistance is concerned, depends largely upon the reduction of this internal friction. We here have an opportunity for effective lubrication, one which is met in the manufacture of transmission rope of the highest class, by the introduction, in the course of manufacture, of sufficient graphite to reduce the internal friction to a very small amount, as compared with a non-lubricated rope.

The use of rope for the transmission of power thus includes in itself in a very interesting manner the action of friction in both of its properties. If it were not for the frictional hold of the rope in the grooves in the sheaves it would not be possible to transmit the power at all, and indeed the transmission of power both by belting and by rope forms a notable instance of the useful application of friction.

The use of graphite as a lubricant of the internal fibres of the rope is an example of the reduction of the hurtful resistance of friction, and the combination of both applications in the one subject shows the manner in which the engineer handles the mechanical problems which arise both to aid and to oppose him in the conduct of his work.

MANILA ROPE

Hunt's Plumbago Laid

—FOR—

Transmission of Power
Pile Driving
Hoisting

Only the longest and best hanks of Manila fibre are selected, and the strongest and toughest of the fibre used in its manufacture.

"There is one way to be sure of economy in buying rope, and that is to take care to get the best brand. The price per pound is of no consequence. What really interests the purchaser is the cost of a certain length of rope strong enough and durable enough to do the work required. Rope which is sold slightly cheaper than the best, may, on being put to a practical test, show an actual value of only about one-third that of the best. Is there any economy in buying such rope even at a cent or two less per pound?" *Trade Paper.*

If you are thinking of buying rope, carefully read the following guarantee

We guarantee that more work can be done with "Stevedore" Rope in proportion to its cost, than with any other rope in the market, without any exception whatever, and will gladly refund the difference in price if it is not all we claim.

You cannot lose one cent by making a trial of this rope, and are sure to reduce your expense account. Before you forget it, purchase a length of this rope to compare with that you are now using.

C. W. HUNT COMPANY

ESTABLISHED 1872

No. 45 BROADWAY NEW YORK

Works: West New Brighton, S. I. NEW YORK

Standardization in Transmission Machinery

STANDARDIZATION in manufactured products is a subject upon which much has been said, and the advantage of standardization as against specialization has been discussed at length and from many points of view. Like all important questions, it has many sides, and it is only by taking the essential features of a given case into consideration that anything like a useful conclusion can be reached. There is little doubt that the systematization of the products of a manufacturing establishment into a limited number of standard articles enables manufacturing costs to be reduced and the general conduct of the business to be simplified. To a large extent it also proves advantageous to the purchaser, since he is able to renew or extend or replace with a certainty of uniformity and with a minimum cost. If, however, standardization is carried too far, or is adhered to in a slavish and unintelligent manner, it acts to bar improvement, to check development, and to paralyze the industry. In some cases it is only by standardization that progress becomes possible at all, as in the case of car couplers, which must interchange to enable cars to pass from one railway to another and to traverse all parts of the country without inconvenience, and it was not until a standard type of coupler was adopted that the use of any automatic coupler could become general.

Another example of the stimulating influence of standardization appears in the production of shafting, pulleys and the general machinery of power transmission. In the older days of mill construction, after the primitive wooden and cast-iron shafting was replaced by the turned iron product, there still elapsed a long period during which no systematic attempt at standardization was made. Shafting was turned to sizes convenient to the diameter of the rough stock and pulleys and gears were bored to fit the particular place where they were to be used. In like manner bearings were either bored to suit the shaft or were babbitted in place, and when a mill or factory was once fitted up the job was regarded as completed. If, at some later date, additional machinery was installed, the necessary pulleys were ordered and the shaft calipered at the point where the power was to be taken off and the pulley attached.

Under such conditions manufacture in the modern sense of the term was impossible. Here was a place where standardization was most imperatively demanded, and here it has been most effectively applied, to the advantage of both manufacturer and purchaser. Shafting purchased to-day is true to size, straight, and interchangeable, both as regards pulleys, couplings and hangers. Pulleys are bored true to size, balanced, and also interchangeable, so that they will go on any shaft of the same nominal size. Couplings, clutches, and all the details which go to make up the transmission system of a modern establishment are made, not to carefully specified dimensions from the purchaser, but are manufactured to standard gauges and sizes, and thus possess immediate adaptability and usefulness. The split pulley enables power to be taken from a shaft at any available point without deranging the other parts of the transmission, and the time required to make changes reduced to a minimum.

This, as already noted, indicates the true use of standardization, the careful systematization and design of a staple product, permitting it to be manufactured instead of built; to be carried in stock rather than made to order; to be replaceable, interchangeable and broadly available wherever needed and whenever required. The standardization appears in points which do not bar or retard improvement, but rather encourage it, so that the standard product is not only far more convenient than the specialized article, but is also better, cheaper and more efficient.

DODGE

The Dodge Line Means Standardization

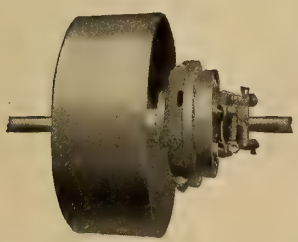
IN the best equipped, most efficient plants all over the country, where the value of standard equipment is appreciated—

¶ There you will find The Dodge Line of Power Transmission Machinery installed throughout.

¶ Please note the advantages these plants have secured.

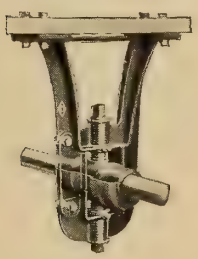
¶ The Dodge Line represents The Dodge Idea—Standardized excellence and interchangeability and the split feature in power transmission machinery.

Dodge Split Friction Clutch with Iron Pulley, Mechanism and Pulley are separate and interchangeable.



Dodge "Independence" Wood Split Pulley. For twenty-eight years the standard, economical pulley for shop work.

Dodge Adj. True Ball and Socket Hanger, with four types of self-oiling bearings.



¶ One complete line of such transmission appliances means quick installation, low cost of maintenance and attendance, and economy of operation.

¶ That is why The Dodge Line would be profitable as *your* shop standard.

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The Development of the Chain Block

WHEN the chain hoist was first introduced it appeared as the rival of the rope tackle. Convenience was the great feature; it could be hung almost anywhere, it could be operated by almost anyone, and it would hold the load, even if the operator let go. At that time the crane in the shop was a rather primitive contrivance, usually of the jib variety, and generally confined to the foundry and the erecting shop. Evolution, however, works out its laws in the mechanical world no less than in the animal kingdom. The appearance of something different from the apparatus which had been transferred from shipboard to land service, something far superior to the wooden blocks and hempen ropes, started the progress and development which to-day is adding its share to the progress of that industrial evolution which has such a profound influence upon present-day work.

The engineer attacked the problem of the power crane and produced what has been termed one of the most highly organized machines of its time. Great traveling cranes spanned the width of machine shop and foundry and covered areas of iron works and shipyards, while power cranes of other types kept pace with the demand. Electric power was pressed into service, and to-day for the heaviest work the traveling crane still holds its eminent position.

Meanwhile, the modest chain block was working out its own line of development and attaining a position where it was to meet its greater rival. The simple differential hoist of Weston did its work well, and has become a staple product. Other types of chain hoist have entered the field, but it was not until the later hoist of Weston—the triplex block—was devised that a degree of mechanical efficiency was attained which permitted a broader field to be entered.

The overhead tramrail enabled the chain block to become a useful means of transporting and handling moderate loads in the machine shop. As the demands became greater the capacity of the block was increased, and it was found that the high efficiency of the mechanism permitted the handling of pieces formerly requiring the services of the power crane. With this extension of the uses of the triplex block came the realization of the fact that the heaviest portion of the work of handling materials lay in the lifting of the weight, and that a hand-operated block with its trolley, from which a triplex block was suspended, formed a combination capable of performing the whole service of handling in the shop up to very considerable limits.

Thus the evolution of the combination has worked itself out in response to the demands of the situation and to the influences of the environment. Increased capacity in the hoisting element of the combination, hand-operated blocks up to 40 tons capacity being regular articles of manufacture, provides the essential mechanical feature of the apparatus. High efficiency, perfect control, both in lifting and lowering, and especial facility in use—these elements of the hoist have been expanded to a capacity sufficiently great to include most of the demands of the shop. When to these there is added a bridge which may be caused to travel the length of the building, carrying a trolley which crosses its width, we have the three dimensions covered and controlled.

It has been remarked by experienced engineers that many devices occur in more complicated forms in the first place, and gradually are reduced to simpler and simpler apparatus as the test of experience is applied, and the development of the chain block is an excellent illustration of this fact. The highly organized mechanism of the traveling crane is, to a great extent, replaced by the simpler combination of the hand traveling bridge and trolley, with the triplex block for the hoist, thus securing simplicity, economy and efficiency.

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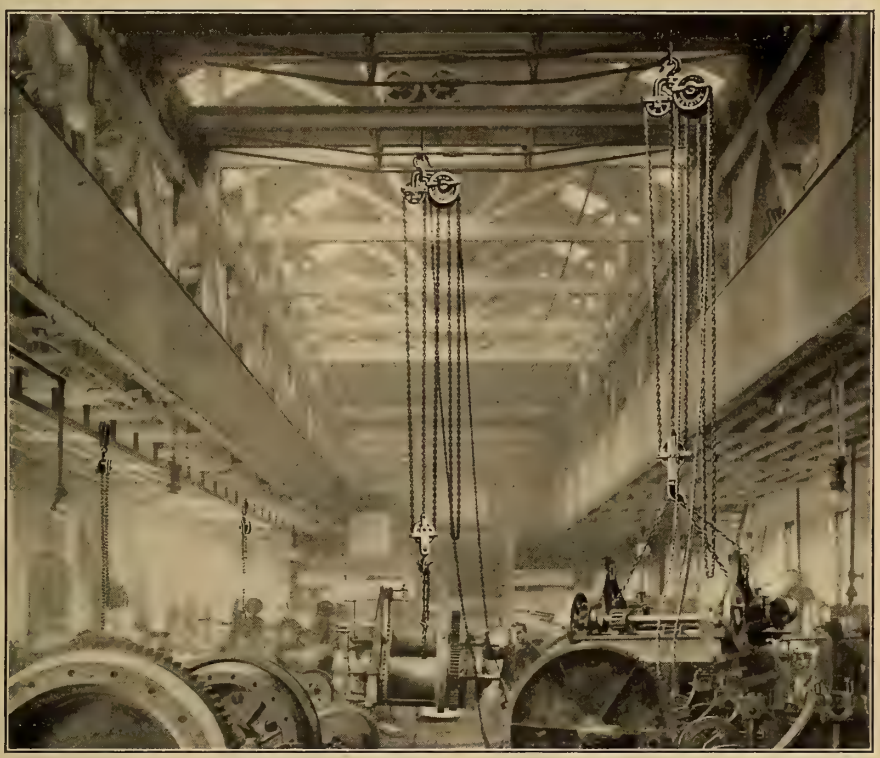

TRIPLEX BLOCKS DOING HEAVY WORK

PICKING up a heavy piece of machinery is only a part of the task—it must be set down again—in the right spot.

And it wants to be done quickly, surely and without interfering in the least with other work.

Nothing has ever met these three requirements in a more satisfactory way than Triplex Blocks swung from an overhead trolley.

They have a lifting capacity up to forty tons, and their mechanism is so simple that one man has them under perfect control. The picture above really tells the whole story.

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Hammer Drill Developments

ONE of the unforeseen developments of mining practice has been the recent and rapid supplanting of the long and firmly established reciprocating piston, bit-carrying drill by the air hammer drill for the ultimate operation of metal mining, the actual liberating of the ore itself. The air hammer drill may now be said to be fully adopted, although, of course, not yet exclusively so, in a field which seems to be especially its own—overhand stoping in soft and medium rock—and the curious thing is that in this it is simply coming back to its original employment.

For cutting metal or stone the instrument first thought of is the chisel struck by a hand hammer, and the first rock drills were chisels, turned to a different position after each hammer-stroke, for larger holes one man holding and rotating the steel while another one, or two others, wielded the sledge; and in the first-tried power drills the chisel or bit held constantly against the rock was retained, the hand hammer or sledge being superseded by power hammers. Then Burleigh and Ingersoll and Sergeant and others came along and made such a success of the reciprocating piston with the drill steel attached that the original idea was dropped entirely, and for a time no one would have predicted that the hammer drill, with its non-percussive bit, would ever come to the front again for mining purposes.

But it has got to work again, and it is a success; and after the fact of its success it is not difficult to find at least some of the reasons for it. The hammer drill is at the beginning a one-man instead of a two-man tool, and for the one man the work of handling it is both lightened and quickened. By the quickening of the handling and the great saving in the time of moving and setting the drill is able to be actually working for a considerably larger percentage of its working time, so that its ultimate rate of accomplishment may be said to be like that of the record-making express train, which makes its record largely by avoiding the long and frequent stops on the way. In one of the largest mining properties in the United States it is stated that one man will drill more ground with a hammer drill than two men with a piston drill. As a result, the cost of stoping has been reduced 25 per cent. wherever the air hammer drills have been used.

The air hammer drill, in its rapid adoption for the special line of work indicated, seems to have made its way upon its own merits rather than to have been pushed forward by interested parties, since the large drill manufacturers are makers of both the hammer drills and those of piston type.

The hammer drill, as compared with the piston drill, is not only a much lighter apparatus as a whole, but is at the same time much simpler. The tripod, with its weights, the bar or column, with their clamps, are eliminated. The telescoping device fixes the drill firmly in position the instant the pressure is turned on, and then serves for the feed as far as the bit will drill. There is no striking of cylinder heads—in fact, no heads to strike—so that the familiar devices for their protection would be superfluous; and there is no rotation ratchet or rifle bar or nut—the most troublesome and rapidly wearing details of the piston drill. The valve motion also is much simpler, one type of hammer drill being actually valveless, while the drill with the valve counts only that single piece more than the other. Between these two types of hammer drills there seems little to choose, but those familiar with either alone can always have interesting discussions with those who handle the other, and each may claim the advantage for his favourite. The air consumption of both seems to be practically the same and decidedly less than that of the piston drill of any make.

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